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NAME OF SUPERVISOR/*NOM DU DIRECTEUR DE THÈSE* TRAVIS W. MANNING

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# ECONOMIC ANALYSIS OF ENERGY USE IN THE MODERNIZATION OF INDIAN AGRICULTURE

by

Ⓒ JAI PRAKASH MISHRA

A THESIS
SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH
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EDMONTON, ALBERTA
FALL, 1977

## THE UNIVERSITY OF ALBERTA

## FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled "Economic Analysis of Energy Use in the Modernization of Indian Agriculture" submitted by Jai Prakash Mishra in partial fulfilment of the requirements for the degree of Doctor of Philosophy.

T.W. Manning
Supervisor

William E Phillips

W.D. Gainer

T.S. Veeman

Gray
External Examiner

Date October 6, 1977

# ABSTRACT

The question of modernizing Indian agriculture is related to the problems of low productivity and unemployment in the agricultural sector and the scarcity of commercial energy resources in the Indian economy. The primary objective of this study was to examine the problems and prospects of energy use in the modernization of Indian agriculture.

India is poor in commercial energy resources. At the same time the consumption of these resources in Indian agriculture has been increasing each year. Annual consumption of main energy items, namely, petroleum and electricity, has more than doubled since independence in 1947. There have been major changes in the pattern of ownership of commercial energy resources. The public share in the ownership of these resources has increased. The coal and electricity industries are virtually controlled by the government. In consideration of the fact that commercial energy resources are scarce and the availability of such resources is necessary for the Indian economy, the Government of India should determine priorities in such a manner as to ensure efficient use of these resources.

Modernizing Indian agriculture depends heavily on the increased use of inanimate energy resources. Since India faces a more or less permanent problem of providing employment for people, the increased use of inanimate energy resources should not result in the displacement of animate energy resources. India's programmes of modernization should aim at achieving increased use of inanimate energy resources, increasing productivity of all energy resources and creating work opportunities in rural areas.

Modern agricultural inputs such as fertilizer, irrigation and tractors involve use of inanimate or commercial energy resources. Increased use of fertilizers and irrigation has played a significant role in increas-

ing cereal production in Indian agriculture. However, there has been no statistical evidence that tractor use has contributed significantly to aggregate cereal production in India. Since tractor use involves a considerable amount of energy expenditure, further studies should be undertaken by the government and research-oriented institutions to examine the importance of tractor use in Indian agriculture.

Tractor use has certain important economic implications for the use of animate energy resources. Increased use of tractor power in tillage operations of wheat, maize and paddy crops results in displacement of human labour and bullock power. One hour of tractor use may render a ploughman and two bullocks unemployed for 1.7 days in wheat cultivation, for 1.2 days in maize cultivation and for 2 days in paddy cultivation. Although such effects are only direct and in-season impacts which abstract from the influence of tractor use on indirect employment and multiple cropping, they may add to the existing unemployment problem in Indian agriculture. The output response of wheat, maize and paddy varies with respect to tractor use in tillage operations. While wheat and maize do not respond to increased tractor use, the paddy crop responds significantly to such use. There is some evidence, therefore, that selective mechanization in tillage operations may play an important role in expansion of rice production in India.

The use of "intermediate technology" may not only result in increased output but also alleviate the problem of unemployment. A major implication of this study is that increased energy productivity can be achieved on relatively modernized farms where increasing use of modern inputs, but not tractors, is occurring. Since India is poor in commercial energy resources and rich in animate energy resources, the strategy for modernizing agriculture should be based, where possible, on "intermediate technology".

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# CHAPTER I

## INTRODUCTION

Academic and government people have been increasingly interested in a means for achieving a rapid growth rate in the Indian economy. The Government of India has repeatedly emphasized the significance of expanding the industrial sector so that the twin objectives of increasing industrial production and employment opportunity in the urban areas can be achieved. The need for increasing agricultural production in order to support the burgeoning industrial sector and population has also been recognized by the government.

A number of initiatives have been undertaken since independence in 1947 to develop the agricultural sector. The task of achieving expanded agricultural production was difficult because a number of reforms were needed. Because of factors such as population pressure on arable land, excessive fragmentation of land holdings, lack of irrigation facilities and outmoded cultivation practices, this sector needed a multi-faceted government programme through which the bottlenecks could be overcome in a systematic way. The worst forms of absentee landlordism were abolished and several large surface water irrigation projects were initiated. The community development and cooperative programmes introduced during the first Five Year Plan (1950-1955), did not bring the expected results because of administrative bottlenecks, lack of technical know-how and inadequate attention to the role of technological change in agricultural production growth.

In the mid-sixties, a genetic breakthrough was achieved in wheat and rice crops. In order to achieve self-sufficiency in food, the government emphasized the use of modern inputs and the adoption of high yielding cereal varieties during the past decade. As a consequence of the modern cereal varieties, the government became hopeful of bringing prosperity to the rural areas. Further impetus was to be provided through more liberal credit facilities extended by the nationalized commercial banks to farmers for the purchase of new seeds, fertilizers, irrigation pumps, tractors and threshers. In response to the increased yield potential of the wheat and paddy varieties and the relatively favourable output prices, farmers began allocating larger areas to these crops. The production of food grains reached a total of 108 million tonnes in 1970-71 and after monsoon failures in 1972 and 1974, an all time record of 120 million tonnes was reached in 1975-76. Although the increased use of high yielding wheat and to a lesser extent, rice varieties did not increase the rate of growth of food grain production, this process of change in agriculture was designated as the Green Revolution.

The results of over two decades of planning for the agricultural and industrial sectors are far from satisfactory. In the first place, the possibility of generating employment opportunities for rural people through pursuing a policy of rapid industrialization is extremely limited, at least in the near future. Secondly, the agricultural sector has not performed as well as hoped in that the food problem still continues to dominate the national scene.

The fundamental theses of this study are that the modernization of the agricultural sector in India is heavily dependent upon the increased use of inanimate or commercial energy and that the strategy of agricultural modernization must reflect the endowments of animate and inanimate energy which the nation possesses.

## Nature and Scope of the Problem

During the last two decades the Government of India has been beset with the problem of providing enough food for its people. The increase in food grain production has barely kept pace with increases in population and, all too frequently, has lagged behind the rate of growth of food demand. The problems of rising food prices and increased food imports have been especially acute in years of monsoon failure.

The developments associated with the Green Revolution (such as increased use of new seeds, fertilizers, irrigation pumps, and tractors) were considered to be an integral part of agricultural modernization. Since 1966-67, the government has been actively engaged in extending and sustaining the Green Revolution.[1] The Green Revolution, became and has remained the cornerstone of agricultural modernization in India.[2] With respect to the current need for enhanced food grain production and agricultural development in India, John Mellor has recently pointed out:[3]

> In the Indian context of the mid-seventies, the public priorities are: (1) to expand the capacity to carry on agricultural research; (2) to increase the area under well controlled irrigation; (3) to increase the supplies of fertilizers; and (4) to extend participation in new technologies to poorer regions and small farms.

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[1] Although the story of the Green Revolution has been repeatedly told in the literature, for a concise presentation see: S. Sen, Reaping the Green Revolution (New Delhi: Tata McGraw-Hill Co., 1975), pp. 3-19.

[2] An account of the fact that the Green Revolution became the cornerstone of the Indian government's policy is also available in: T.S. Veeman, "Economic Consequences and Policy Implications of the Green Revolution in India with Particular Emphasis on Water Resources Policy in Punjab" (Ph. D. Dissertation, University of California, Berkeley, 1975).

[3] John W. Mellor, The New Economics of Growth--A Strategy for India and the Developing World (Ithaca, New York: Cornell University Press, 1976), p. 73.

Each of these priority areas, with the possible exception of the need for agricultural research, involves a concomitant requirement for greater use of commercial energy resources in the agricultural sector. To increase domestic supplies of fertilizer will necessitate imports of petroleum-related feedstocks. The provision of more adequate and well-controlled water supplies is intimately tied to increased ground water pumping, particularly in the Indo-Gangetic plain of Northern India. This, in turn, requires increased rural electrification and enhanced supplies of electric power and diesel fuel to operate ground water pumping sets and tubewells.

A further and emerging policy concern with energy ramifications is the rapidly increasing number of tractors in some agricultural areas in India, chiefly the wheat zone of Northern India. To this point in time, of course, the total number of tractors in Indian agriculture is relatively small and bullocks provide an overwhelming share of draft power. However, partly as a facet of modernization policy and more particularly due to pressure from larger farmers, the government has encouraged farmers with relatively large land holdings to purchase tractors and heavy equipment by providing subsidies and liberal credit arrangements. This policy has two implications for Indian agriculture: (1) it makes the agricultural sector even more dependent upon the international oil market, and (2) the use of heavy machines in agriculture displaces a considerable amount of human labour and bullock power which are abundantly available in the country.

This increased use of and need for commercial energy resources is cause for some concern because India is poorly endowed with petroleum resources. Even before the Green Revolution, imports of fossil fuels were substantial, and their increasing use in agriculture will be an added drain on scarce foreign exchange reserves. For this reason and because of the abundance of rural labour and draft animal resources, an expansion of food production cannot simply be a question of the supply of modern inputs to the agricultural production process. Agricultural development strategy for India should also be conditioned by such factors as the indigenous endowment of inanimate or commercial energy resources, by the constraint imposed by scarce foreign exchange, and by the need for providing employment for an expanding and already underemployed labour force.

A strategy for modernizing Indian agriculture based on the western agriculture experience is bound to set off many serious problems for the Indian economy and for the agricultural sector in particular. It is important to examine whether modernization can occur in the Indian setting without having to consider the use of large-sized tractors and associated mechanical equipment. In other words, the meaning and scope of the modernization of Indian agriculture should be examined in the context of the potential for "intermediate technology".

Yet another important aspect of agricultural modernization associated with the adoption of high yielding varieties of wheat and rice crops is that these crops have enjoyed the benefit of breeding research. In particular, their yield potentials have gone up to a significant extent and some of the varieties are very well suited to Indian climatic conditions. Because of these advantages, farmers began allocating larger areas to these crops. While such a trend is important to modernization, further scope for increasing the area under these crops is limited. In recent years, the prices of pulses have increased considerably, especially in comparison with prices of cereal commodities. If pulse prices keep on increasing relative to cereal prices, farmers may start allocating larger areas to pulse crops.[1] If this possibility occurs, it might decelerate the adoption of high yielding varieties of cereals. Since the yield potentials of pulse crops are very low and these crops can be grown without use of modern inputs such as fertilizers and irrigation, a switch from the cultivation of cereal crops to pulse crops may dampen the demand for fertilizer and irrigation and linkages which have gained momentum during the process of the Green Revolution.

## Research Objectives

The general objective of this study is to analyze and discuss the problems and prospects of energy use in the modernization of Indian agriculture. The specific research objectives are:

1. To examine the trends in consumption of commercial energy resources in Indian agriculture.

2. To discuss the aspects of availability of energy resources in the Indian economy and their significance to the agricultural sector.

3. To develop a perspective on agricultural modernization in India in the Green Revolution experience and attendant economic problems or interfaces associated with energy use in Indian agriculture.

4. To determine the productivity of the important energy resources in the light of the Green Revolution experience.

5. To examine the effect of power intensity on wheat, maize and

---

[1] During the last two decades, a number of studies on the economic rationality and supply response of the Indian farmers have been done. Each of the studies showed that the Indian farmers were responsive to the prices of the commodities which they produced.

paddy outputs in a situation in which more tractor power is substituted for human labour and bullock power and to determine the significance of both types of energy resources in performing the tillage operations in the crops under study.

6. To examine the impact of the changing structure of prices on the adoption of high yielding varieties of crops.

7. To modify or redefine the concept of agricultural modernization to fit Indian conditions and to examine the effect of such modernization on the productivity of energy resources in wheat cultivation.

## Background and Format of the Study

The study involved the use of published data, farm data, and experimental data. For collection of published data, the author visited several libraries, including the United States Library of Congress, International Bank for Reconstruction and Development, Cornell University, Ford Foundation, New York City, International Development Research Centre, and the High Commission for India in Ottawa. The farm data were collected from the Centre for Farm Management Studies at Agra and the experimental data were obtained from the Govind Ballabh Pant University of Technology and Agriculture in Pantnagar, Uttar Pradesh, India.

The study required formulation of economic models. The validity of each model was examined by way of incorporating the data into the models and performing econometric analyses. In particular, regression analysis was used in several instances. The analysis and results of the study are presented in the following format. In chapter II the nature and extent of the dependence of India's agricultural sector on commercial energy resources are discussed. In Chapter III a brief discussion of reserves, annual production, the geographical distribution, the organization, and the problems and prospects of each of the major energy resources of India is provided. The meaning and scope of the modernization of Indian agriculture are discussed in Chapter IV.

Chapter V has been devoted to an examination of the role of major energy-related inputs such as fertilizers, irrigation and tractors in aggregate cereal production in India. In Chapter VI the implications of tractor use for crop yields and in-season employment of human labour and bullock power have been analyzed. Finally, in Chapter VII, the productivity of important energy resources used in wheat production was analyzed and compared on relatively modernized and non-modernized farms in a district of North India.

# CHAPTER II

## AGRICULTURAL USE OF COMMERCIAL ENERGY RESOURCES IN INDIA

Agricultural use of commercial energy resources was practically nonexistent in India prior to 1950. The new government which was faced with the task of modernizing the Indian economy recognized that living conditions and production in rural areas were extremely unsatisfactory. Various agencies and experts concluded that in order to increase agricultural production, farmers had to be motivated to adopt improved practices in cultivation of crops. The government encouraged the use of tractors and other equipment among those farmers whose landholdings were large. The genetic breakthrough in wheat which was achieved in 1963-64 provided impetus to the government programmes for expanded food production. Since then the main theme of Indian agricultural policy has been oriented towards increased adoption of high yielding varieties of wheat, maize and paddy crops. For successful adoption of high yielding varieties of crops, inputs such as seeds, fertilizers and irrigation are required. Various agricultural operations such as ploughing, seeding, weeding and harvesting need to be performed at the correct time. Because of these requirements, the government started making efforts to arrange supplies of inputs and equipment (i.e., fertilizers, irrigation pumps, and to a lesser extent, tractors and combine harvesters). In the Indian economy, the use of these inputs has been increasing since the inception of new technology.

The changing picture of Indian agriculture attracted the attention of government planners and agricultural economists. A number of studies on fertilizers, irrigation and tractor use in India have been made. The studies lent support to the increased use of new inputs in Indian agriculture. In particular, fertilizers and irrigation were designated the principal inputs for successful adoption of the new technology.

As a result of the sudden increase in crude oil prices in 1973, the question of judicious use of energy resources became a matter of paramount importance. A separate ministry for energy was created in India. It has now been established that at current prices energy resources such as oil and coal will not continue to be available for a long time. For Indian agriculture such a possibility has many implications in that it will adversely affect the process of adoption of new technology and thereby total food production. This chapter, therefore, is devoted to examination of the changing pattern of use of commercial energy resources in Indian agriculture and its significance to the Indian economy.

## The Changing Pattern in Use of Commercial Energy Resources in Indian Agriculture

### Fertilizers

The genetic breakthrough achieved in the production of wheat and paddy crops has given rise to problems such as additional resource requirements. Prior to the start of the Green Revolution, farmers applied very little fertilizer in the production of wheat and paddy crops. The practice of fertilizer use was confined to sugarcane and tobacco production. During the last decade, however, the use of fertilizers has become common in wheat and paddy cultivation. As a result, the annual consumption of fertilizers has increased exponentially.

The annual consumption of nitrogen has increased drastically. It increased from 57,800 tonnes in 1953-54 to 434,500 tonnes in 1964-65. The annual consumption of phosphate and potash (which is very low in comparison

FIGURE 1

Annual Consumption of Fertilizers During The Pre Green Revolution Period

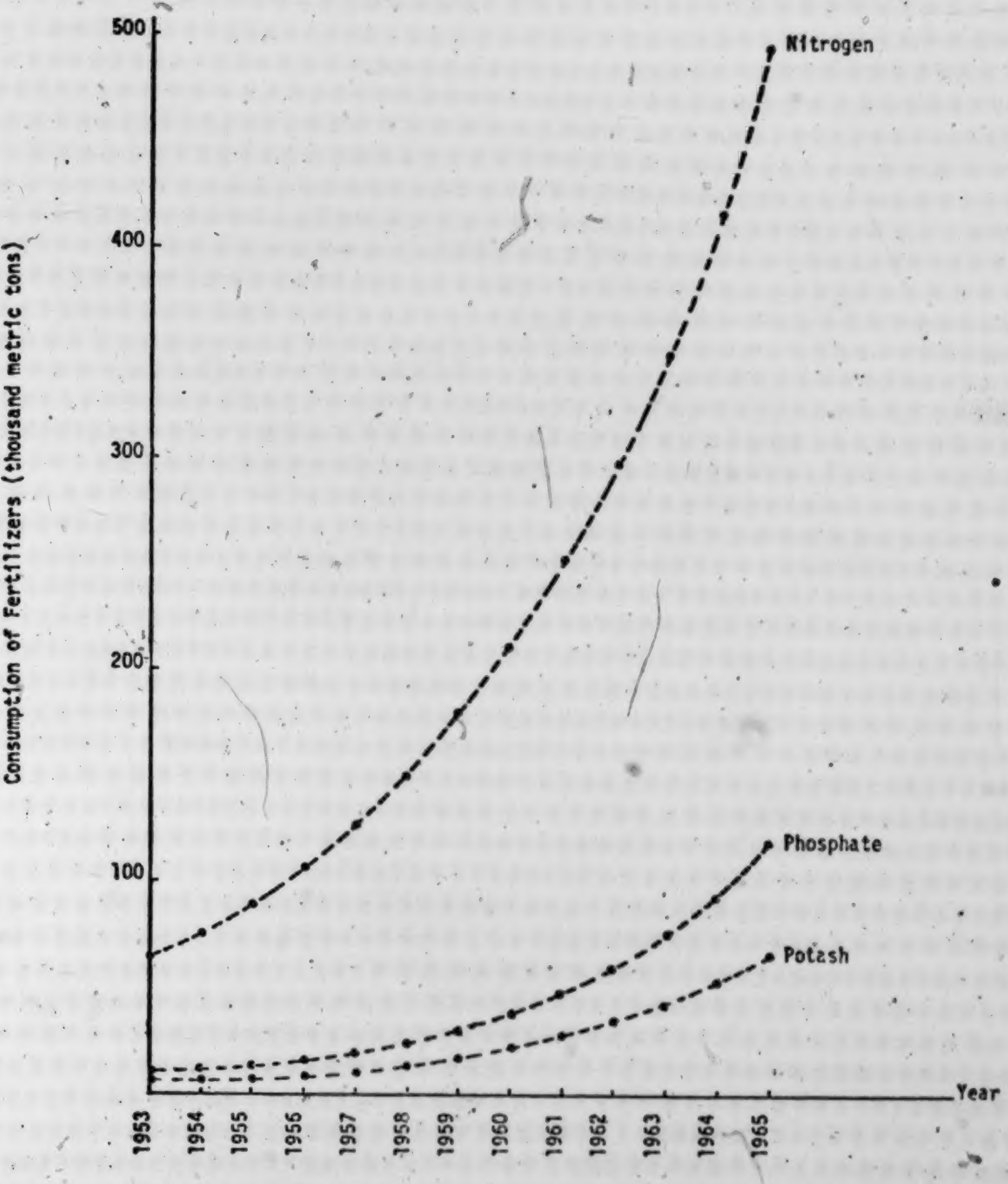
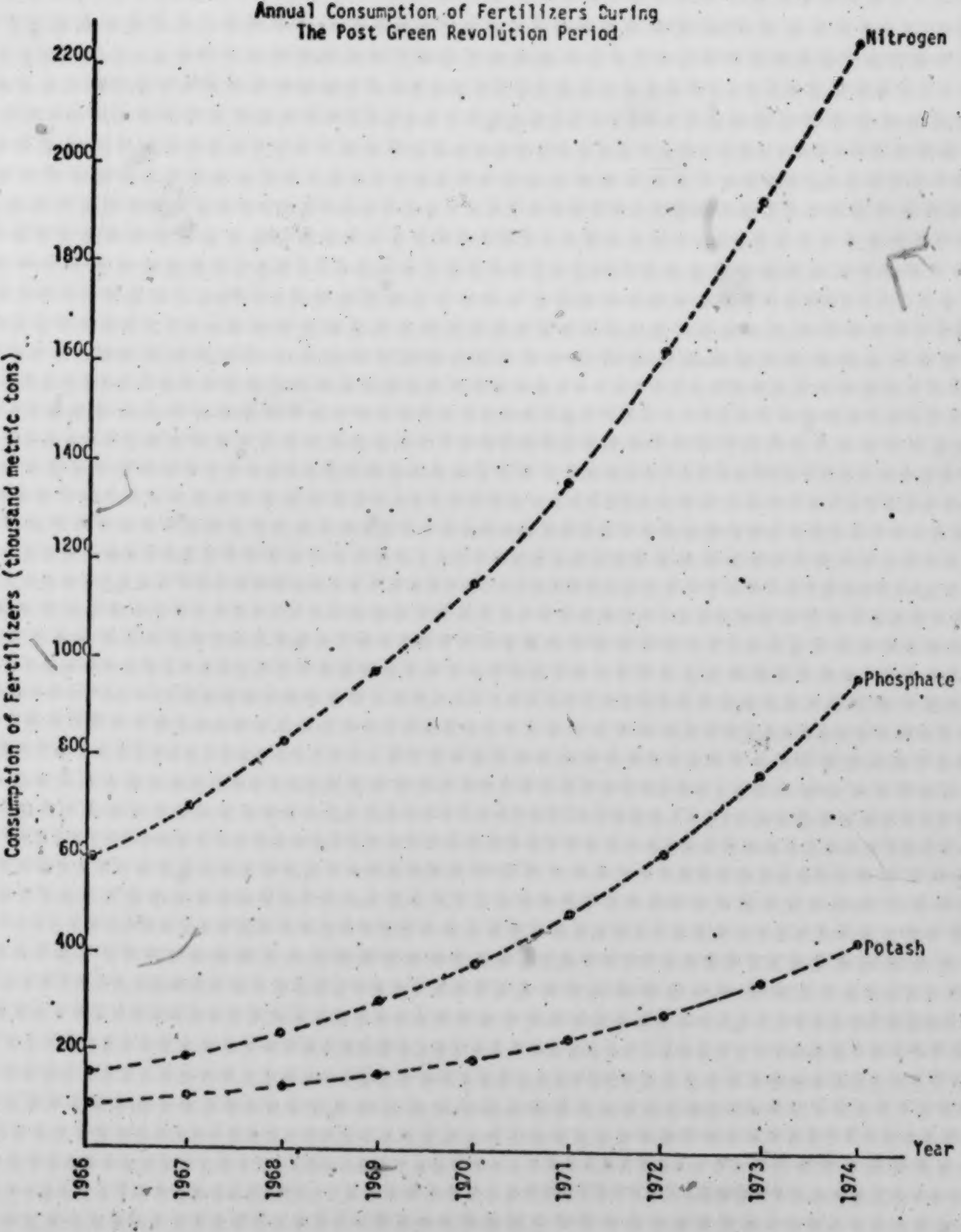


FIGURE 2
Annual Consumption of Fertilizers During The Post Green Revolution Period



with nitrogen) also increased in a similar manner. The consumption of phosphate increased from 4,600 to 147,700 tonnes and potash use increased from 3,300 to 70,400 tonnes during the corresponding period (Figure 1).

The years following 1966 witnessed a tremendous increase in the consumption of fertilizers (Figure 2). Regression of the annual consumption of each nutrient against time shows that the use of nitrogen, phosphate and potash over the period 1953 to 1974 increased at annual compound rates of 17, 23 and 21 percent, respectively.

The use of fertilizers has indeed boosted food production in that during 1975-76, India reaped a record harvest of 120 million tonnes, whereas this figure was in the neighbourhood of 60 million tonnes annually in the fifties. However, the exponential growth of fertilizer consumption is indicative of the fact that the agricultural sector is becoming energy intensive in the process of rural transformation. As a consequence, its dependence on the industrial sector and imports has been increasing (Table 2.1).

In spite of the fact that the share of imports of nitrogenous

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[1] Increases in annual consumption of nitrogen, phosphorous and potash follow exponential trends as will be observed from the expressions below.

(i) $Cn = 54.40 \quad e^{0.169953t}$
$\quad (81.002) \quad (45.243) \qquad r^2 = 0.9903 \quad DW = 1.5979$

(ii) $Cp = 5.867 \quad e^{0.231836t}$
$\quad (17.876) \quad (30.772) \qquad r^2 = 0.9793 \quad DW = 1.1545$

(iii) $Ck = 4.346 \quad e^{0.207765t}$
$\quad (18.051) \quad (33.526) \qquad r^2 = 0.9825 \quad DW = 1.6226$

where Cn, Cp, and Ck represent annual consumption of nitrogen, phosphorous and potash, in thousand tonnes, respectively. Figures in the parentheses are the 't' values of the constant term and the coefficient associated with the time, respectively. They are all significantly different from zero at the 1 percent level of probability.

## TABLE 2.1

## QUANTITIES OF IMPORTED FERTILIZERS AND THEIR SHARE IN TOTAL FERTILIZER CONSUMPTION

| Particulars | 1952-1953 | 1964-1965- | 1973-1974 |
|---|---|---|---|
| Quantity of Nitrogen, Imported[1] | 44.3 | 256.5 | 660.6 |
| Quantity of Phosphate, Imported[1] | 0.0 | 12.3 | 214.4 |
| Quantity of Potash, Imported[1] | 3.3 | 70.4 | 314.0 |
| Percentage of Imports in Total Nitrogen Consumption | 76.64 | 59.03 | 36.00 |
| Percentage of Imports in Total Phosphate Consumption | 0.0 | 8.32 | 33.75 |
| Percentage of Imports in Total Potash Consumption | 100.0 | 100.0 | 100.0 |
| Value of Imported Fertilizers[2] | 45.6 | 242.5 | 1,460.0 |

[1] Figures in thousand tonnes (1 tonne = 1,000 kilograms).

[2] Figures in million rupees.

Source: Consumption of Fertilizers Fertilizer Statistics (New Delhi: The Fertilizer Association of India, 1974), pp. 73-97.

fertilizers has been declining, the total amount of foreign exchange involved in imports has been increasing. This is mainly due to the increase in area under high yielding varieties. The data presented in Table 2.1 also suggest that domestic production of fertilizers has increased. In this regard, it is important to note that import content pervades through domestic production also. For instance, indigenous production of nitrogenous fertilizers involves the use of naphtha which is a petroleum product largely procured through imports. Thus, in the transformation process, Indian agriculture has become dependent on external sources of energy supply.

## Irrigation

Prior to the Green Revolution, pump irrigation was not popular in India. Farmers generally depended on monsoons. Early arrival of the monsoon would encourage larger areas in paddy and late arrival would force the farmers to allocate large areas to millet crops (i.e., those crops which can thrive in poor moisture conditions). Farmers were nevertheless aware of the significance of irrigation. For this purpose, they depended on wells. Use of power pumps was limited to a small number of holdings which were usually larger than average.

There has been a rapid adoption of modern technology since independence. Over the period 1951-1971, the number of power pumps in operation rose from 85,000 to 275,000.[1] During the corresponding period, there was hardly any net addition to the number of traditional waterlifts. This kind of changing situation is important in the context of the energy intensiveness of Indian agriculture in that the traditional method of irrigation used a greater amount of animate energy than modern methods. For instance, human operated waterlifts such as counterpoise, picotta and chain pumps require two, five and four men per day in their respective operations. Similarly, use of animal operated waterlifts such as rope and bucket and the Persian wheel involves two men per day. Also, a pair of bullocks is required in each of these methods.[1] As opposed to traditional methods, modern techniques depend heavily upon inanimate energy items such as petrol, diesel, and electricity. The use of bullock power in modern techniques is practically non-existent and only a modicum of human effort is required.

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[1] B.D. Dhawan, "Economics of Ground Water Utilization: Traditional Versus Modern Techniques," Economic and Political Weekly, Vol. IX, Nos. 25 and 26 (June 21 and 28, 1975), pp. A31-42.

The modern techniques for lifting irrigation water are time-saving. When using traditional methods, the daily output of water ranges between 5,000 and 18,000 gallons whereas an irrigation pump can easily supply 8,000 gallons of water per hour.[2] The genetic breakthrough in the production of wheat and paddy crops has had a lot to do with the rapid installation of irrigation pumps in India. Farmers quickly became aware that irrigation must be adequate, timely and well controlled if the new technology of crop production was to be successfully adopted. As a result, the number of applications for electric power connections increased considerably. The changing situation in the number of irrigation pumps operated by electrical power is given in Table 2.2.

Increased use of electric pumps has taken place in those areas

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[1] Ibid., p. A-35.

[2] Ibid., p. A-31.

## TABLE 2.2

## NUMBER OF ELECTRIC IRRIGATION PUMPS

| Year | Number of Electric Irrigation Pumps ('000) |
|---|---|
| 1950-51 | 21 |
| 1955-56 | 56 |
| 1960-61 | 198 |
| 1965-66 | 509 |
| 1968-69 | 1,081 |
| 1970-71 | 1,619 |
| 1971-72 | 1,890 |
| 1972-73 | 2,186 |
| 1973-74 | 2,440 |

Source: P.D. Henderson. India: The Energy Sector (Washington, D.C.: International Bank for Reconstruction and Development, 1975), p. 75.

where hydro power has already been developed. Diesel powered pumps have become popular in areas such as Maharashtra and Gujarat where hydro power has not been introduced. For example, Maharashtra State, which contains 13.2 percent of India's total arable land, has 18.4 percent of total diesel pumps. Gujarat State, which contains 6.9 percent of total arable land, has 8.7 percent of India's diesel pumps.[1]

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[1] See: K.N. Raj, "Mechanization of Agriculture in India and Sri Lanka (Ceylon)," International Labour Review, Vol. 106, No. 4 (October 1972), pp. 315-334.

The growth in demand for installation of power pumps has not been evenly distributed throughout India. However, the agricultural sector is becoming energy intensive while the animate energy component in the irrigation system has been declining. In the process of rural transformation, therefore, the requirement for inanimate energy resources has gone up.

## Tractors

Whether tractors are an important ingredient for increasing productivity in Indian agriculture remains a controversial issue. However, there has been a tremendous increase in the number of tractors in India. In 1951, the total number of tractors was 8,000 whereas in 1971, it increased to 174,000.[1] In addition to the problems of displacement of human labour and bullock power, the rapid growth in the number of tractors has another adverse feature. It has made the agricultural sector dependent on external forces such as arrangements for imports and the pricing behaviour of oil producing countries.

## Seed

The production performance of the high yielding varieties of crops also depends on the quality of seeds. Grains produced on the farmers' fields should be treated with chemicals before they are used as seed. The seed multiplication programme received support from various state governments as well as the Government of India. A number of seed processing plants were installed in the late sixties. In recent years, use of certified seeds has become popular among Indian farmers. Part of the increase in energy intensiveness of Indian agriculture is also due to the increased use of certified seeds.

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[1] Ibid., p. 316.

## Summary

The Indian agriculture sector is becoming more and more dependent on commercial energy resources each year. Since more food grains will be required to support the ever increasing population in the country, the Government of India will continue to emphasize its policy of increased adoption of high yielding varieties of crops. Therefore the requirement for commercial energy resources will further increase.

# CHAPTER III

## ECONOMIC ASPECTS OF INDIA'S ENERGY RESOURCES

Various ideas and theories have been put forward by economists for improving the economic well-being of the people of the Third World countries. The theories vary in measure and proportion in that while one school suggests the need for a "big push" the other emphasizes the need for a "balanced growth".[1] Although a considerable dissimilarity exists in the theoretical constructs, the treatment of technology is more or less similar. The central focus of all the schools of thought is on the improvement or transformation of technology.

In the wake of shortages experienced by the oil-importing countries during 1973 onward, concern about the knowledge of energy resources has gained impetus. It has been realized that the growth and development of any region are very much dependent upon the quantity of energy resources which are available to it. The manner in which energy resources are utilized has also become an object of inquiry. Energy scarcity is a matter of serious concern for the Third World countries (excluding the oil exporting countries). Their bargaining power in the international market is weak and thus the prospects of procurring energy resources through imports have not been very bright in the past. At the same time use of commercial energy resources is extremely important in the modernization of traditional systems. Consequently, the technological options must take into account the availability of energy resources in a country.

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[1] See V.V. Bhatt, "Theories of Balanced and Unbalanched Growth," Economic Development Challenge and Promise, eds. Stephen Spiegelglas and Charles J. Welsh (Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1970), pp. 104-113, for a concise treatment on the above theories.

Estimates of energy needs are derived on the basis of targets set for growth in the industrial and agricultural sectors. For instance, the estimates of crude oil requirements are derived on the basis of projected requirements of middle distillates over the planning period. The increase in imports of oil has become a serious constraint on the prospects for growth in that the amount required for oil imports alone is likely to account for 50 percent of India's export earnings. The problem will continue unless measures are taken to substitute alternative energy resources for petroleum products. An examination of various aspects of energy resources is considered necessary (e.g., the trends in production and consumption and the nature of the energy supplying industries).

## Commercial Energy Resources

### Coal

Coal is by far the most important of the indigenous sources of energy supply. It provides employment to a considerable number of workers and it is available in abundance. It is the principal fuel in steel production, railway traction and electricity generation.

#### i) Reserves

Estimates of proven, indicated and inferred reserves of coal are given for the year 1972 in Table 3.1. These figures are essentially the Geological Survey of India estimates. Estimated total reserves are about 81 billion tonnes. The stock of proven and indicated reserves is 52 billion tonnes. The current annual consumption of coal in India is estimated at 73 million tonnes. The total available reserves of coal are sufficient for 713 years provided that future annual consumption remains

Table 3.1

ESTIMATED COAL RESERVES IN INDIA
(Million Tonnes)

| Type of Coal | Proven Reserves[1] | Other Reserves Indicated[2] | Other Reserves Inferred[3] | Total Reserves |
|---|---|---|---|---|
| 1. Coking Coal | | | | |
| a) Prime Coking Coal | 3,650 | 1,540 | 460 | 5,650 |
| b) Medium Coking Coal | 3,850 | 4,310 | 1,270 | 9,430 |
| c) Semi & Weakly Coking Coal | 1,520 | 2,600 | 910 | 5,030 |
| TOTAL Coking Coal | 9,020 | 8,450 | 2,640 | 20,110 |
| 2. Non Coking Coal | 12,340 | 22,310 | 26,180 | 60,830 |
| TOTAL Coal Reserves | 21,360 | 30,760 | 28,830 | 80,950 |

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[1] Proven Reserves: Those reserves which are within 200 meters of mining operations.

[2] Indicated Reserves: Those reserves which are, within the points of observation, not more than 1,000 meters apart or 2,000 meter beds of known continuity.

[3] Inferred Reserves: Those reserves about which estimates have been derived on the basis of broad knowledge of the measures, even though there is no quantitative evidence within 2,000 meters.

Source: P.D. Hendersen, India: the Energy Sector (Washington, D.C.: International Bank of Reconstruction and Development, 1975), pp. 6-7, Table 1.

the same. On the other hand, if we assume that the annual consumption increases at a rate of 5 percent, the reserves are adequate for only 72 years.

ii) Production

The annual production of coal has increased significantly during the post-independence period. However, the trend in the annual production is marked with variation in that, until 1966, there was a constant increase, whereas it reached a plateau during the seventies (see Table 3.2).

TABLE 3.2

OUTPUT OF COAL AND LIGNITE IN SELECTED YEARS
(Million Tonnes)

| | 1956 | 1964 | 1966 | 1970 | 1971 | 1972 | 1973 |
|---|---|---|---|---|---|---|---|
| Coal | 39.43 | 56.06 | 67.97 | 73.70 | 71.49 | 74.77 | 77.06 |
| Lignite | - | 0.06 | 2.57 | 3.54 | 3.66 | 3.07 | 3.30 |

Source: Central Statistical Organization, Government of India, Monthly Abstract of Statistics, Vol. 27, No. 4 (April, 1974), pp. 6.

iii) Geographical Distribution

The important coal mines, namely, Raniganj and Jharia, are located in the eastern states (i.e., Bengal and Bihar) of India. These mines have been in existence for a long time and even today they contribute more than 60 percent of total production. During the last two decades, a number of coal fields have been discovered and the mining operations therein have begun.[1]

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[1] For details see: P.D. Henderson, India: the Energy Sector (Washington, D.C.: International Bank for Reconstruction and Development, 1975), p. 10, Table 3.

Important among those are Singareni and Neyveli in the states of MadhyaPradesh and Tamil Nadu (formerly known as Madras). The Singareni coal fields are rich in coking and noncoking coal, whereas the Neyveli fields are rich in lignite. The distribution of coal is quite uneven in the country in that most of the coal production comes from the eastern and southeastern states (see Figure 3).

### iv) Organization of the Coal Industry

The structure of ownership of industries has undergone a considerable change during the last two decades in India. The share of the private sector in ownership of coal mines declined from 89.3 percent in 1954 to 3.4 percent in 1974 (Table 3.3).

TABLE 3.3

SHARE IN PRODUCTION BY SECTORS

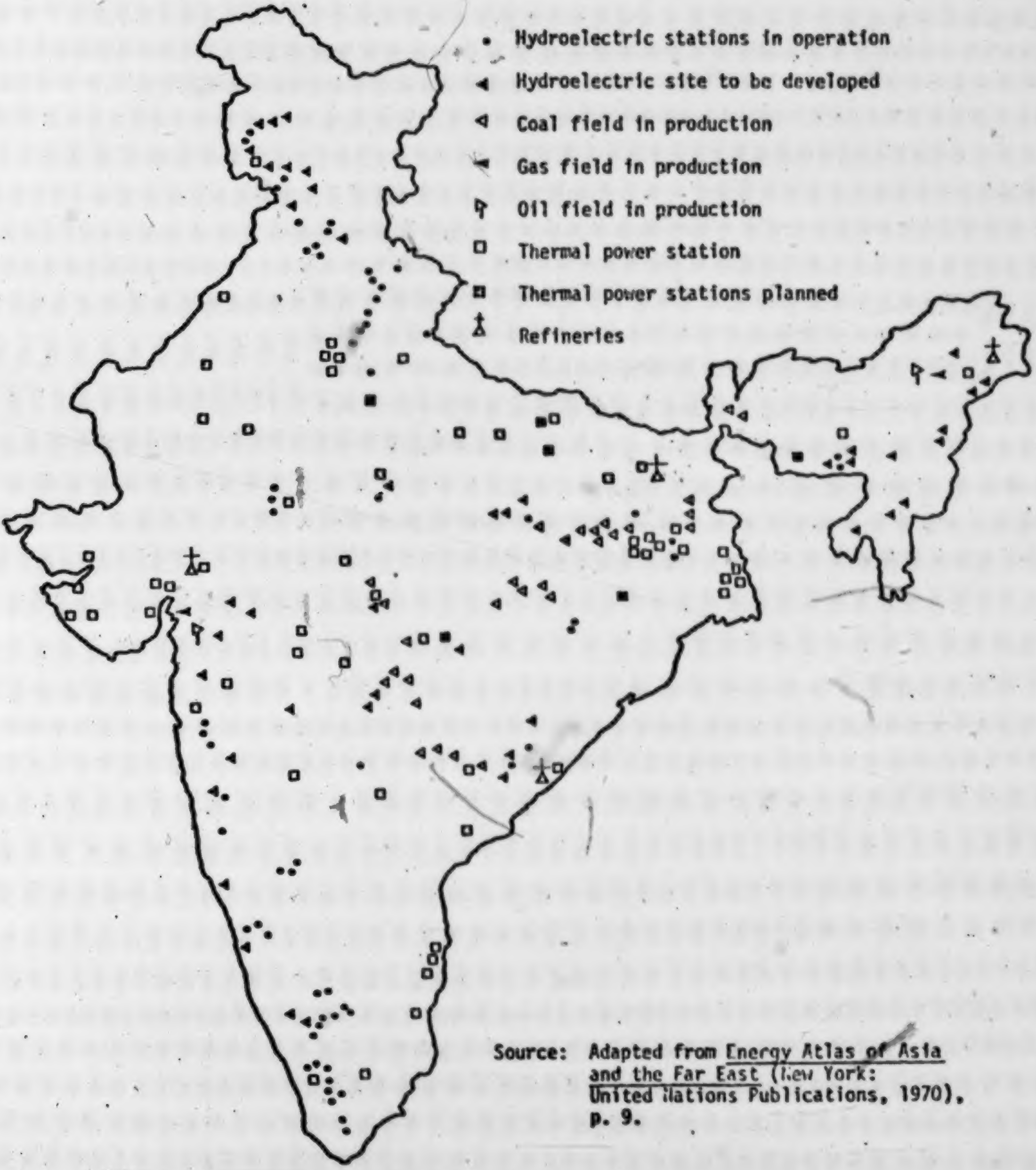
| | 1954 | 1960-61 | 1965-66 | 1968-69 | 1969-70 | 1970-71 | 1971-72 | 1972-73 | 1973-74 (Provisional) |
|---|---|---|---|---|---|---|---|---|---|
| Public Sector | 10.7 | 19.0 | 20.0 | 23.1 | 23.1 | 24.4 | 34.9 | 53.5 | 96.6 |
| Private Sector | 89.3 | 81.0 | 80.0 | 76.9 | 76.9 | 75.6 | 65.1 | 46.5 | 3.4 |

Source: The relative shares have been worked out on the basis of data presented by P.D. Henderson, India: the Energy Sector (Washington, D.C.: International Bank for Reconstruction and Development, 1975), p. 39.

While the structure of ownership has changed, there have been concomitant changes in the administrative structure of the publicly

FIGURE 3

Energy Map of India


• Hydroelectric stations in operation
Hydroelectric site to be developed
Coal field in production
Gas field in production
Oil field in production
Thermal power station
Thermal power stations planned
Refineries

Source: Adapted from Energy Atlas of Asia and the Far East (New York: United Nations Publications, 1970), p. 9.

owned coal mines. Previously, the administrative powers had been vested in the National Coal Development Corporation. Consequent upon the formation of the Ministry for Energy in 1974, various responsibilities for control, expansion, research and development were transferred to this ministry.

v) Problems and Prospects

The coal industry suffered serious setbacks during the past two decades. The main setbacks were: i) stagnation in production and ii) low productivity of workers. Annual production reached a plateau during the late sixties. Since then the increases have been marginal. The annual output per worker is about 180 tonnes, which is much less than European and North American standards (average output per worker in the U.K. and Canada is 480 and 3,161 tonnes, respectively).

There has been an element of uncertainty among the private owners regarding their tenure on the mines. As a consequence, both management and expansion have deteriorated. Also the trade unions became very active in their demands during the sixties. An absenteeism rate of 13 percent has become a permanent feature.[1] As a consequence, production performance has remained unsatisfactory.

The demand aspects of the coal industry have played a significant role in poor production performance. The reasons are deep-rooted and seem to have their origin in the various government strategies for utilization of fuel. The Government of India was actively engaged in achieving rapid industrial growth during the first decade of the post-independence period.

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[1] Central Statistical Organization, Government of India, Monthly Abstract of Statistics, Vol. 27, No. 4 (April 1974), p. 5.

Demand for coal was dependent on the government's fuel policy. During the early sixties, the use of petroleum products was encouraged by the government. Such a policy was bound to have its effect on the relative prices of coal and thereby on the profitability of the coal industry. In consequence, research and development of coal uses did not receive the attention of the government.

The management of the coal industry is now in the hands of the government. The outcome of this change in ownership is yet to be seen, as it will depend largely on the policies of the government and the extent of cooperation among various organs therein. For instance, a serious bottleneck in the industry has been the transportation of coal from mines to various destinations. Most coal is transported by rail. Thus the degree to which the transport bottleneck will be overcome will depend upon the efforts made by the Ministry of Railways.

## Petroleum

The significance of petroleum to an economy cannot be overemphasized. The annual requirement of oil has increased during the post-independence period. Petroleum has become very important in the agriculture sector. In the first place, it is used as a feed stock in fertilizer factories. Secondly, it is the principal fuel for irrigation pumps.

### i) Reserves

Reserves of petroleum are exceedingly small in comparison with coal. They are estimated at 10.2 billion barrels. The petroleum reserves are also very small in relation to the current annual use of 1.3 billion barrels.[1] However, the planners are hopeful about further discovery of oil reserves in the offshore areas of the Arabian Sea and Bay of Bengal. Oil reserves have been found in the Bombay High Area and drilling operations have already begun. Further success will depend upon the exploration efforts of the Oil and Natural Gas Commission.

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[1] See Central Statistical Organization, Government of India, Monthly Abstract of Statistics, Vol. 27, No. 4 (April 1974), p. 6.

### ii) Production

Although India depends heavily on imports to meet petroleum requirements, it has accelerated domestic production of crude oil to a significant extent during the post-independence period. It started with 14.52 million barrels in 1951 and its annual production is now about 400 million barrels. (Table 3.4). While annual production between the fifties and the sixties increased by more than ten times, it reached a plateau during the seventies. More investment for purchase of drilling equipment will be needed for a further increase in crude oil production.

TABLE 3.4

PRODUCTION OF CRUDE OIL IN SELECTED YEARS
(Million Barrels)

| | 1954 | 1956 | 1961 | 1966 | 1970 | 1971 | 1972 | 1973 |
|---|---|---|---|---|---|---|---|---|
| Crude Oil Production | 14.52 | 21.78 | 29.38 | 255.42 | 374.22 | 395.34 | 405.90 | 396.00 |

Source: Adapted from Central Statistical Organization, Government of India, Monthly Abstract of Statistics Vol. 27, No. 4 (April 1974), p. 4.

### iii) Geographical Distribution

The oil fields are located in two states (i.e., Assam and Gujarat). Drilling activity has been in existence for a long time in Assam.

The Gujarat oil fields are new and were brought into operation during the sixties. The distribution of oil fields is uneven in that while the Assam oil fields are in the far eastern part of the country, the Gujarat oil fields are in the extreme western part (see Figure 3). The problems due to uneven distribution of oil fields is not as great as that of the coal fields in that the shipment of oil is not a big problem.

### iv) Organization of Industry

A large part of the petroleum required in the industry is procured through imports. Mostly crude oil is imported. The government has always preferred domestic processing of distillates rather than direct imports. In consequence, a number of refineries have been installed in the country. Presently there are nine refineries in operation. As well, one refinery at Mathura is yet to be commissioned.

Unlike the coal industry which is largely under public ownership, the oil industry has both public and private ownership. Some ventures have both components (viz., public and private). These fall in the category of "joint sector".

The Government of India has control over 50 percent of the oil industry. The government's control and expansion programmes are effected through three principal organizations (i.e., Assam Oil Company, Oil India and the Oil and Natural Gas Commission).

### v) Problems and Prospects

The share of the industrial sector in the gross domestic product has been increasing. Simultaneously, employment opportunities in the industrial sector have increased. Most importantly, its foreign exchange earnings have considerably increased. The agricultural sector has also performed well during recent years. The development of these features was made possible by progressive use of oil in transportation, steam generation, manufacturing of various items including fertilizers and mechanization of agriculture.

Another area of concern is the growth of refineries in India and the technology used. The government had two available policy options for meeting the requirements of diesel fuel, petrol and kerosene. It could either import these items directly from the oil exporting countries, or it could import crude oil and process it in its own refineries. The government opted for the latter. The observations made by Bhatia are revealing:

> Briefly, this approach assumes that it is more economic to import crude oil than petroleum products. The quantum of crude throughput is estimated in terms of the quantities of middle distillates (kerosene, aviation fuel and diesels) required. To illustrate, if the demand for kerosene and diesels is estimated at 1 million tonnes, the quantity of crude to be processed is estimated as 2.38 million tonnes.[1]

The government policy for installation of refineries does not stand the test of economic rationality on two grounds. Firstly, the installation of refineries eroded the foreign exchange reserves. Secondly, government began encouraging use of heavy stock (accumlated at the refineries) as a principal fuel in industrial installation. In fact, use of heavy stock as a fuel was preferred over coal by the government. The latter affected profitability in the coal industry and thereby its production performance. Thus the policy for meeting the requirement of diesel fuel, kerosene and petrol through indigenous processing has gone against the coal industry.

Refinery processing is an area of concern in India. It stops at the completion of primary processing, (i.e., extraction of middle and light distillates). While a number of secondary processes have already been developed, it is startling to note that no efforts have been made for further extraction of light and middle distillates from the residues of the primary processing. For instance, the heavy stock (i.e., the chief residue) is used as furnace fuel although the secondary processing of the heavy stock can alleviate the scarcity of light and middle distillates to a considerable extent.

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[1] For a detailed discussion on the oil policy of the Government of India see Ramesh Bhatia, "The Oil Crisis: An Economic Analysis and Imparatives," Economic and Political Weekly, Vol. IX, No. 30, (July 27, 1974), pp. 1191-1203.

The prospects of alleviating the problems due to mounting import bills will depend upon relations between India and the oil exporting countries and upon the efforts put into exploration for offshore oil. For the latter, external assistance will be necessary in that the main expertise for offshore oil exploration lies with the American firms and if they are given attractive rights, further discovery of offshore oil can be exploited.

## Natural Gas

Interest in natural gas is only a recent development in comparison with that of coal and oil. In India, the production of natural gas commenced during the mid-fifties as a result of public interest. The growth of the industry has not been rapid. The main reasons is that the cost of putting in the pipelines is high. Its use will gain popularity as it has in the Western world, provided there are enough reserves of natural gas. Despite the small size of the industry a brief discussion in respect of various features of the industry is considered important.

i) Reserves

In India natural gas occurs independently and with crude oil. The proven reserves are estimated at 63 billion cubic meters.[1]

ii) Production

Estimates of the annual production of natural gas differ from source to source. For instance, for the year 1961, Darmstadter and others[2] estimated the annual production as 107 million cubic meters, whereas the Indian Bureau of Mines estimated 168 million cubic meters for the same year. Notwithstanding the differences in estimates, there is similarity in the trends in annual production. Over the years, the production of natural gas has gone up in the country. Annual production of natural gas increased significantly during the sixties but it reached a plateau in the seventies. (Table 3.5).

TABLE 3.5

PRODUCTION OF NATURAL GAS IN SELECTED YEARS
(Million Cubic Meters)

| | 1961 | 1966 | 1970 | 1971 | 1972 | 1973 |
|---|---|---|---|---|---|---|
| Natural Gas Production | 168 | 372 | 672 | 756 | 924 | 924 |

Source: Central Statistical Organization, Government of India, Monthly Abstract of Statistics, Vol. 27, No. 4 (April 1974), p. 6.

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[1] P.D. Henderson, India: the Energy Sector (Washington: D.C.: International Bank for Reconstruction and Development, 1975), p. 14.

[2] Joel Darmstadter, Perry D. Teitelbaum and Jaroslav G. Polach, Energy in the World Economy (Washington, D.C.: Resources for the Future Inc., 1971), p. 250.

### iii) Geographical Distribution and the Organization of Industry

Areas of production are located in Assam and Gujarat states. The locations have already been described.

As for the organization of the industry, its ownership is largely held by the public sector. The control of the industry and the expansion programme are effected through the Oil and Natural Gas Commission, Government of India.

### iv) Problems and Prospects

The problems of the natural gas industry are transportation problems. Transport involves high costs which, at the current prices of fuels, are not economically feasible and thus it poses serious problems for its utilization. In fact, even today, when the country is undergoing serious problems due to energy shortages, only 55 percent of the annual production is put to use and the remaining 45 percent is flared. (Table 3.6)

TABLE 3.6

RATE OF UTILIZATION OF NATURAL GAS IN SELECTED YEARS

| | 1965 | 1966 | 1967 | 1968 | 1969 | 1970 | 1971 | 1972 | 1973 |
|---|---|---|---|---|---|---|---|---|---|
| Percent | 47 | 46 | 38 | 46 | 53 | 47 | 50 | 59 | 55 |

Source: Ministry of Petroleum and Chemicals, Indian Petroleum and Chemical Statistics, 1973, Quoted in Henderson, India: the Energy Sector (Washington, D.C.: International Bank for Reconstruction and Development, 1975), p. 15.

Natural gas has a variety of uses and its low utilization rate is a matter of concern. Nearly 416 million cubic meters of natural gas is flared each year in India. This amounts to wasting 2.44 million barrels of crude oil. Alternatively, it could be utilized in steam generation or fertilizer production.

## Hydro and Thermal Power

Electricity generation has received a considerable impetus in India during the last two decades. Concomitant with the increase in production, its utilization has also increased. Various facets of the Indian economy, such as the industrial and agricultural sectors, have equally benefited from the increased electricity production.

This industry is of great significance to the Indian economy in that the country still possess a great potential for increasing its availability through indigenous resources. Currently, it is produced from three resources (i.e., water, coal and uranium), and accordingly, two sources of electrical energy are generated, (1) hydropower and (2) thermal power. Electrical energy generation from nuclear plants is a fairly recent development. We shall briefly examine the main aspects of the industry in the following sections.

### i) Production

As indicated before, the production of electricity has increased significantly during the last two decades. This has been made possible by increasing the installed capacity of the hydro and thermal power stations and by increasing efficiency. Like the coal industry, the electricity industry has emerged as a public sector enterprise. In the following table, data in respect of installed capacity and actual electricity generation by the public utilities are given.

### TABLE 3.7

### INSTALLED PLANT CAPACITY AND PRODUCTION OF ELECTRICITY IN SELECTED YEARS

| | 1951 | 1956 | 1961 | 1966 | 1970 | 1971 | 1972 | 1973 |
|---|---|---|---|---|---|---|---|---|
| Installed Plant Capacity (million KW) | 1.835 | 2.886 | 4.653 | 9.027 | 14.102 | 14.709 | 15.254 | 16.282 |
| Total Production (billion Kwh) | 5.856 | 9.612 | 19.116 | 34.152 | 54.948 | 58.920 | 64.200 | 66.324 |

Source: Central Statistical Organization, Government of India, *Monthly Abstract of Statistics*, Vol. 27, No. 4 (April 1974), p. 6.

ii) Geographical Distribution

Since electrical power is generated from two principal sources (i.e., hydro and thermal), its geographical distribution is fairly even in various regions of India. For instance, in the north and northwestern regions, there is a considerable hydro-power potential and, accordingly, electricity is generated mainly from the hydro resources. Thermal power generation is largely concentrated in the areas of coal production. Nuclear power is generated from the two plants which are located in the states of Maharashtra and Rajasthan. These areas are deficient in respect of both conventional resources (i.e., hydro and coal resources). Various regions with their power generation potentials have been indicated in Figure 3.

### iii) Problems and Prospects

The utilization of electricity is one of the most serious areas of concern because ultimate consumers of electricity are located at great distances from places of production; a considerable amount of electricity is lost in transmission. For instance, during the years 1970, 1971 and 1972, transmission losses were 17 percent.[1]

Another problem area is the utilization of installed capacity. Hydro-power generation is affected by seasonal variation in riverflows. Thermal power generation is affected by the transport bottlenecks in shipping the coal to the thermal power plants.

The costs involved in transmission are a determining factor in utilization. It is because of the problems associated with installing transmission networks that some of the areas are still devoid of electrical power.

In the coming years, the demand for electricity will increase because its competitive position in relation to oil has improved. Nearly 72 percent of the villages still remain to be brought under the electrification programme. Thus the prospects of the industry, so far as the demand is concerned, are good. The improvement in supply will depend upon the development of hydro, thermal and nuclear power. The three sources of electricity generation deserve equal emphasis because coal and hydro resources are distributed in an unequal manner. The costs involved in transmission of electricity to those areas which are far away from the point of production could pose a serious problem. Nuclear power plants are the only alternative for electrical energy in those areas.[1]

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[1] The figure was derived from data presented in Central Statistical Organization, Monthly Abstract of Statistics, Vol. 27, No. 4 (1974), p. 6.

## Noncommercial Energy Resources

A number of noncommercial energy resources are of immense significance. Estimates of their use are not readily available from the existing system of data collection in India.

The Energy Survey of India Committee of 1965 also faced the problem of data collection. In recognition of the fact that estimates of energy uses in domestic cooking were necessary in assessing the total energy requirement and that this type of energy is chiefly derived from wood, crop-residues, and cowdung, the Committee conducted a survey of selected villages. The average expenditure so determined was used in assessing the total amount of energy obtained from the various noncommercial energy resources. The procedure adopted by the Committee is considered to be very comprehensive and the study is considered to be a landmark.[2] We shall briefly examine the features of the noncommercial energy sources and the problems and prospects emanating from them.

### i) Production

Noncommercial energy sources can be grouped into three categories

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[1] See R.K. Sinha and N.L. Sharma, Mineral Economics (New Delhi: Oxford and I.B.H. Publishing Co., 1970), pp. 287-242, for a discussion of the advantages of nuclear energy in the Indian economy.

[2] See Arjun Makhijani and Allan Poole, Energy and Agriculture in the Third World (Cambridge, Mass.: Ballinger Publishing Co., 1965) and Roger Revelle, "Energy Use in Rural India" Science 192 (June, 1976), pp. 969-975 for a detailed discussion on the significance of the study conducted by the Committee.

(viz., cowdung, waste products and firewood). The annual use of these resources has been increasing.

ii) Problems and Prospects

In all rural India and in a large part of the urban area, the main sources of energy are noncommercial. Even at the current rate of consumption, the available quantities may not be adquate after a few years.

Part of the problem of scarcity of noncommercial resources can be solved if proper measures are taken by the government. The use of these resources is rather extravagant in that these are burnt in open-fire systems. Thus the efficiency of these resources is low compared to a closed-fire system. If the open-fire system is replaced with the closed-fire system, a considerable amount of energy can be saved.

Recent developments in utilization of these resources are of considerable importance. For instance, adoption of bio-gas plants, (i.e., the plants for generating methane from cowdung and crop residues)[1] can increase the availability of energy significantly. The success will depend upon the efforts made by the government.

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[1] For details see, Arjun Makhijani and Alan Poole, Energy and Agriculture in the Thirld World (Cambridge, Mass.: Ballinger Publishing Company, 1975), pp. 143-158.

# CHAPTER IV

## MODERNIZATION AND INDIAN AGRICULTURE

In the history of mankind there has always existed differences or dissimilarities in economic, social and political performances among countries, races and groups of people. Consequently, some societies or countries progressed so rapidly that their values and technology of production became worthy of emulation by the people of those countries and races whose economic and social environment did not witness such changes and whose living conditions were vastly inferior to those of people in advanced societies.

During British rule, the Indian people started taking interest in learning the English language, thereby adopting it as a medium of instruction. During the nineteenth and the early part of the twentieth century, the "landed gentry" began emulating the habits and traits of the British. During the same period, transportation underwent changes and a railway network was established for both travel and shipment of goods. People started migrating into the areas of industrial activity, mainly for jobs and schooling and to become part of the urban community. In the meantime, the mode of production changed in the urban areas. Huge industrial installations were established.

These changes have been looked at with interest, mainly with a view to analyzing the causes and consequences. Accordingly, a need for labelling the nature and type of transition arose. For instance, the adoption of the English language as a medium of instruction was labelled as "Anglicization"; the people who adopted the traits, habits and other aspects of the British were labelled as "Anglophils"; the people who moved from villages to townships were called "urbanized"; and so on. Each of these transitions was a step towards progress in its own right and therefore designated as "modernization".

During later years, particularly during the second World War, the dissimilarities between the advanced and backward countries assumed many dimensions. By that time, the U.S. had emerged as a vastly superior nation. The progress made by the U.S.S.R. and Japan was worthy of attention. For India, as well as for many other countries, the meaning and scope of modernization no longer remained limited to the European style of living and its methods of production.

Concomitant with the changes which were occurring in various parts of the world, scholars in various disciplines started taking interest in describing the nature of the changes, the root causes thereof and the likely consequences on the polity, society and economy of a given region. Areas in which this concern became prominent are economics, sociology, anthropology, and political science.

As to the developing countries, the main focus of scholarly interest was to determine a modus operandi from the experience of the "developed world" through which various problems of human life could be alleviated. Accordingly, these scholars devoted attention to examining various aspects of life prevailing in the Third World countries. For instance, the immediate concern of economists was to find a way in which the productivity of various resources in a given region could be enhanced; political scientists were interested in the distribution of power and responsibility in a given system in which participation by the people and stability of the system could be ensured; and sociologists were concerned with the development of individuals having traits such as a universalistic attitude and high aspirations.

The kind of transition needed in the developing countries was designated as "modernization" by scholars, regardless of their discipline. The term "modernization" therefore is used to designate the different kinds of transition and lacks universal conceptual clarity. The focus here is on modernization in economic terms.

## Conceptualizing Agricultural Modernization in India

In conceptualizing modernization, some economists have examined at length the economic aspects of projects launched in the Third World countries and have developed the concept in their own way. For example, in the Thana and Comilla areas of East Pakistan (now Bangladesh), a project for the development of agriculture was launched in the 60's. The farmers in the project area were provided with adequate credit facilities and improved quality of seed. As a result, the farmers allocated large areas under paddy. Farouk and Rahim[1] have designated this programme as a "modernization programme". In their analysis of the project, they observed that upon implementation of the project, the marketable surplus of paddy increased significantly. To them, therefore, modernization of agriculture is a process which directly results in increased "marketable surplus" of certain commodities produced in a given area.

In India, an experiment was launched in 1960-61 in selected districts (viz., the Intensive Agricultural District Programme). The features of the Programme were:[1]

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[1] A. Farouk and S.A. Rahim, Modernizing Subsistence Agriculture: An Experimental Survey (Dacca: Bureau of Economic Research, University of Dacca, 1967), pp. 1-18.

1) Adequate farm credit, based on production potential, made readily accessible to the farmers

2) Adequate supplies of fertilizers, pesticides, improved seeds, improved farm implements and other essential production needs made available through strengthened service cooperatives.

3) Price incentives to participating cultivators through assured-price agreements for rice, wheat and millet, announced two years in advance.

4) Marketing arrangements and services which enable the cultivator to obtain full market price for his marketed suplus.

5) Intensive educational, technical and farm management assistance made available in every village in every development block of the district.

6) Participation of all interested cultivators, both large and small, in direct individual farm planning for increased food production.

7) Village planning for increased production and village improvement programmes, strengthening of the village organizations and leadership.

8) A public works programme using local labour to undertake drainage, bunding, soil conservation, minor irrigation, building of approach roads and other development works contributing directly to increased agricultural production.

9) Analysis and evaluation of programme after its inception.

10) Coordinating on a priority basis by village, block, district, state and centre all resources essential to mount and carry out the

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[1] Expert Committee on Assessment and Evaluation, Modernizing Indian Agriculture: Report on the Intensive Agricultural District Programme (1960-68) (Nasik: Government of India Press, 1969), pp. 3-4.

programmes with maximum speed and effectiveness.

While evaluating the "programme", the Expert Committee on Assessment of the Intensive Agricultural District Programme concluded that modernization could be measured along the continuum of adoption of the high yielding varieties of wheat, paddy and maize crops. The basis of conceptualization in this approach is the observed changes in the allocation of resources in the main enterprise (i.e., agriculture, in this case) which occur as a result of programmes such as I.A.D.P.

Wellisz[1] has conceptualized modernization in a similar manner. Modernization to him must essentially involve a rapid substitution of new machines and new production methods for traditional equipment and methods of production. In this regard, new managerial methods must be adopted and a considerable improvement in transportation, storage, wholesaling and retailing must be brought about.

The other approaches in conceptualizing modernization are those of Enke,[2] Mosher[3] and Wharton.[4] They are also worthy of attention.

Essentially, Enke's approach to modernization of agriculture in developing countries refers to three aspects: (1) consolidation of land holdings, (2) specialization in output, and (3) improvements in the methods of cultivation. In Indian agriculture, for example, land holdings are excessively fragmented. Due to excessive fragmentation, a considerable amount of labour time is wasted in going from one piece of land to another. Thus, despite the fact that the size of land holdings is small, farmers are unable to put in the required effort in tilling the land and maintaining constant watch over the crops due to fragmentation of land holdings. In consequence, the productivity of resources is adversely affected. Specialization in output refers to the need for changing the existing pattern from a highly diversified type to a relatively specialized one. The farmers in India cultivate a number of crops during a growing season despite the fact that the size of holdings is small. As a result, the productivity potential of various resources is not fully exploited. Similarly, the method of cultivation is considered one of the causes of low productivity. For example, the broadcast method of seeding is common among most of the farmers in various regions of the country. Because of this practice, crop management is seriously affected as a sizable number of plants are damaged during the weeding operation. In addition, it also prevents intercultural operations which are extremely important for plant growth and development. Adoption of improved methods can enhance the labour productivity substantially.

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[1] Stanislaw H.Wellisz, "The Modernization of Technology," Modernization: The Dynamics of Growth, ed. Myron Weiner (New York: Basic Books, Inc., 1966), pp. 233-245.

[2] Stephen Enke, Economics for Development (Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1963), pp. 159-163.

[3] A.T. Mosher, To Create a Modern Agriculture: Organization and Planning (New York: Agricultural Development Council, Inc., 1971), pp. 29-37.

[4] Clifton R. Wharton, Jr., "Modernizing Subsistence Agriculture," Modernization: The Dynamics of Growth, ed. Myron Weiner (New York: Basic Books, Inc., 1966), pp. 258-269.

Wharton and Mosher have suggested that agricultural modernization must involve a greater and greater introduction of economic factors. To them, the essentials of modernization are: (1) transportation, (2) market for products, (3) new farm technology, (4) availability of purchasable inputs, and (5) incentives. Their approach is similar to that of the

Intensive Agricultural District Programme. In both approaches, the concept of modernization essentially implies that the process of change in agriculture must be accompanied by increased linkages (both forward and backward) and increased productivity of resources.

These definitions of modernization, along with those of other economists, serve specific purposes which differ from the purpose of this study. Therefore none of these definitions can be readily adopted for use herein.

The root causes of transition in any society, whether backward or advanced, are: (1) ability of people to use inanimate energy resources and (2) the proporiton of inanimate energy used in a given system. The effects of the transition are reflected in increased productivity and capacity, and in the increased development of human personality.

The use of inanimate energy resources is of great significance in modernization. In the history of any civilization, progressive increase in the use of inanimate energy resources was an important factor. People in various civilizations made use of wood, wind and water to harness energy and power for burning, navigation and milling. In the present day, use of inanimate energy resources has increased; people in advanced countries have become largely dependent upon inanimate energy resources. In underdeveloped countries the use of inanimate energy resources is increasing. Whether it is a valid change for them is worthy of attention. For example, in India, where animate energy resources are abundant in relation to other resources, progressive use of inanimate energy may result in a considerable displacement of human labour. If the effects are of this nature, the direction of the economy may not result in modernization.

In the context of Indian agriculture, modernization involves a process which results in increased use and productivity of animate energy resources. Increased use of inanimate energy appears to play an important catalytic role in modernization process. For instance, a considerable amount of inanimate energy is required in fertilizer production, ground water pumping and selective mechanization.

A system will progress towards modernization if the ratio of inanimate to animate energy resources increases along with a greater participation of the members of the society in various productive activities. On this basis, various entities such as farms and entrepreneurial activities can also be classified as modernized and non-modernized. However, the concept essentially connotes a state of relative transition. Therefore, it will be more appropriate to designate an entity either "relatively modernized" or "relatively non-modernized".

## Some Features of Traditional Agriculture in India

The modernization of Indian agriculture is conditioned and constrained by the nature of traditional agriculture which predominates the Indian rural scene. Some important features of traditional agriculture in India which bear upon the modernization process are briefly discussed.

The Nature and Size of Units-- Agriculture is the main occupation in rural India. It is a source of livelihood for those who own land and also for those who work for the landowners such as blacksmiths, farm labourers, potters, etc. Because of the tremendous pressure on land, the land holdings are small and crops are grown primarily for meeting the consumption needs of the rural households. An average farmer allocates part of his land for cultivation of cereal crops (viz., wheat, paddy and maize and barley) and another part for pulse crops (viz., chick peas, peas, arhar, lentils, etc.). Regardless of the size of holding, the cropping pattern on the individual farms is highly diversified.

The distribution of land holdings is unequal. While a large number of farmers own a small proportion of land area, a small number of farmers own a large proportion of land in many regions of the country.

## Media of Exchange and Extent of Linkages

Most of the exchange of goods and services takes place within the village itself. The barter system is still prevalent in the rural areas of India. Barbers, washermen, blacksmiths, and farm labourers receive a certain quantity of grain from the land-owning families during each harvesting season in exchange for their services. Only a small proportion of output is sold to the markets outside the village. This sale takes place through the itinerant dealers who frequent the villages during the post-harvesting season. The market system for the food grains is not well developed in the country except in a few agriculturally advanced areas such as Punjab and Haryana States and the Western and Terai regions of Uttar Pradesh State.

The main feature of the linkages between farm families and markets outside the village is the sale of surplus produce. This transaction also occurs through the itinerant dealers. It is done primarily for meeting the fiber requirements of the families. This feature is still predominant in the Indian setting despite the claims made by experts that both backward and forward linkages have gained momentum with the onset of the Green Revolution. While such claims could be true of the farmers belonging to the agriculturally advanced regions, these are not tenable for the majority of people living in the rural areas.

## Mode of Production and Transportation

Production is carried out using locally produced equipment such as picks, spades, deshi ploughs, planks, "Persian wheels", etc. These are employed through human labour and bullock power (i.e., the animate sources of energy). The main vehicle for hauling produce is the bullock cart; thus, even in transportation, mostly animate energy is used. Therefore the tools used in production and transportation in the Indian setting are sedentary when used with animate sources of energy.

In addition to these tools the other inputs used in agricultural production are also modest. For example, farmers apply manure in order to provide nutrients such as nitrogen, phosphorous and potash. The chemical energy required for growth and development of plants is obtained from the animate sources (i.e., dung which is obtained from the bullocks and cows on the individual farms).

In connection with production, a reference to the type of seeds used is also necessary. Unlike the farmers of the advanced countries, most Indian farmers use home-produced seeds. Although with the advent of new varieties of wheat and paddy, farmers have begun to use newly developed seeds, a large number still do not.

Thus the systems of production and transportation are such that most of the requirements are met through the animate sources of energy available within each family unit and through locally available knowhow. The use of inanimate sources of power in traditional agriculture is sporadic and modest.

## Selected Aspects of Agricultural Modernization

Considering the background presented in the preceding section, the question of modernizing Indian agriculture essentially relates to the aspects given below.

### Adoption of High Yielding Varieties of Crops

During the early sixties, a genetic breakthrough occurred. The Mexican selections (Lerma Rojo, Sonora 64) were found to be well suited to Indian climatic conditions. Since then a number of wheat varieties have been developed in India. Popular among these are Sona Kalyan, Sonalika and Tripple Dwarf Gene. During the late sixties, the performance of I.R.8 (i.e., international rice variety) was found to be satisfactory under Indian conditions. In later years, a number of paddy varieties were developed at the various research centers-- Jaya, Padma and Ratna varieties are by far the most popular among them. With regard to the maize crop, a number of hybrids were developed.

The above varieties have much higher yield potential than the traditional varieties. Adoption of these varieties by farmers will enhance the productivity of various resources including that of human labour.

### Assured Availability of Critical Inputs

Performance of the high yielding varieties largely depends upon the use of two kinds of inputs (viz., fertilizers and irrigation). These are considered to be critical inputs since the yield potential of the new varieties cannot be fully exploited unless certain quantities of these inputs are applied to the crops. In Indian agriculture, the use of these inputs has become popular. However, progress in this regard is sporadic and is mainly confined to the agriculturally advanced regions. Under existing practices, farmers with small land holdings do not apply the required quantities of fertilizers and irrigation water. Therefore, in order to achieve higher productivity of resources, proper arrangements for the supply of these inputs to all kinds of farmers (i.e., regardless of the size of holdings) must be made.

### Development of Financial Infrastructure

In India, a popular saying goes: The Indian farmer is born in debt, lives in debt and dies in debt. Farmers have to rely on the village money lenders for credit. The rates of interest charged by these people are exorbitant, varying from 24 to 60 percent per annum. The government launched a campaign for the establishment of cooperative societies during the early years of independence. For various reasons, this "movement" did not bring expected results.

Lately commercial banks have entered agricultural financing. Their experience appears to be satisfactory. Development of this kind of financial infrastructure will certainly alleviate the credit problems of the farmers in that assured credit facilities will enable them to purchase the critical inputs required in the adoption of the high yielding varieties of crops.

### Marketing Arrangements

The sale of surplus produce is effected through itinerant dealers who take food grains to the "mandis" or grain markets. Sometimes the village money lenders themselves purchase the surplus produce. These intermediaries pay much less to the farmers than the actual prices prevailing in the grain markets.

Poor marketing arrangements affect modernization of agriculture in a rather indirect manner. Since farmers do not get reasonable prices for their produce, their ability to invest in agricultural activities is adversely affected. Consequently, the productivity of various resources remains low.

In recent years, public sponsored programmes have been launched with a view to purchasing food grains directly from the farmers. The purchases are effected through the Food Corporation of India and the Provincial Cooperative Federations. Under this programme, mainly those farmers with relatively large land holdings and sizeable quantities of grains for sale are covered. The benefits of these programmes have not penetrated to the farmers with small land holdings. In order to bring about a uniform level of modernization, programmes for providing adequate marketing facilities to all farmers must be launched.

## Storage Facilities

Because of the small size of land holdings, most farmers have small quantities of surplus produce. The farmers generally store the surplus produce in their dwelling houses. It has been reported on various occasions that a considerable amount of damage occurs to the surplus produce because of poor temperature and humidity control in the dwellings. Rats and other pests also cause damage. Farmers are therefore deprived of the incomes they would get if proper storage arrangements existed.

In most of the agricultural areas, individual farmers have neither the means nor the knowledge to construct storage godowns. Because of the small size of surplus produce, construction of storage facilities by individual farmers may prove uneconomical. For this purpose, organized storage facilities in the rural areas are needed.

## Education of Farmers

The technical knowledge required in the cultivation of improved varieties of crops is an important factor which affects the productivity of human labour. Farmers sometimes are not able to achieve the yield potentials of the crops, despite expenditure on critical inputs such as seed, fertilizers and irrigation.

A reasonably good network of agricultural research has been developed under the leadership of the Indian Council of Agricultural Research. Research pertaining to agriculture is also carried out by the agricultural universities. This network of research is of great benefit to the agricultural sector. What is needed is a constant flow of information about new developments from the research centres to the rural areas. This can be made more effective by demonstrating the results obtained at the research centres on the farmers' fields.

Providing education to farmers is a tremendous task. It should be basically oriented towards expanding the ability of a farmer to translate the experimental results on his own farm. He should at least become aware of the significance of new techniques in cultivation of crops and the timeliness of operations such as seeding, weeding, irrigation and harvesting. Education to farmers will therefore require a great deal of effort on the part of the government.

## Other Aspects

There are several other aspects which should receive the attention of the people responsible for achieving modernization. Prominent among them are: (1) transportation in rural areas; (2) provision of electricity connection for irrigation and domestic lighting purposes; and (3) consolidation of land holdings to enable the farmers to make long term investments such as installation of irrigation pumps, land leveling, construction of irrigation channels and fencing arrangements.

The modernization on Indian agriculture calls for a concerted and multifaceted programme. The main objective should be to achieve a significant increase in production although this alone is insufficient to achieve modernization. There are some important interfaces which are linked to an increase in productivity. Without regard to those interfaces, the objectives of modernizing Indian agriculture cannot be accomplished. A brief discussion in respect of each of the modernizing interfaces, therefore, is considered necessary.

## The Interfaces in Modernizing Indian Agriculture

### a) Availability of Inanimate Energy Resources

The use of inanimate energy resources is an integral part of the agricultural modernization strategy based upon modern varieties, adequate and timely irrigation, increased fertilizer use and selective mechanization. Other aspects of modernizing Indian agriculture are also intimately related to the availability of inanimate energy resources: the development of transportation and communication; the construction of storage godowns, and irrigation infrastructure; land leveling; the provision of education, and research pertaining to agriculture, etc. For agricutlural modernization, oil and electricity are the two main requirements. Most of the improved techniques in agriculture involve the use of either of these resources. Thus, availability of inanimate energy resources is an important interface in the context of modernization.

## b) Animate Energy Resources

An important question is whether the use of machinery is a step towards modernization in Indian agriculture. Granted that use of machines involves greater use of inanimate energy resources and simultaneously enhances the productivity of human labour, but the issue at hand is the effect of machine use on the employment of agricultural workers, especially in India. Use of the tractor renders workers and bullocks redundant to a significant extent. The displacement of animate energy resources is of great consequence in that the agricultural sector currently employs 200 million workers[1] and depends on 70 million bullocks for power. The utilization of animate energy resources is intimately related to the use of inanimate energy resources and thereby to agricultural modernization.

## c) Relative Changes in Food Grain Prices

Modernization results in increased productivity of labour and an increased crop output. The cropping pattern prevailing in an area must be carefully considered. No breakthrough has occurred in pulse crops. Because of the high yield potential of wheat and paddy varieties during recent years, the area under these crops has been increasing. Consequently, the per capita availability of cereals in the country has increased. This change has an important bearing on the structure of food grain prices in the country. Although the availability of cereals has increased on a per capita basis, the per capita availability of pulses has declined as a result of the increased area of wheat and paddy crops. Thus pulse prices have been increasing at a faster rate than cereal food grain prices in recent years.

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[1] T.S. Veeman, "Economic Consequences and Policy Implications of the 'Green Revolution' in India with Particular Emphasis on Water Resources Policy in Punjab" (Ph.D. dissertation, University of California, Berkeley, 1975), p. 20.

The widening gap between cereal and pulse prices is a matter of interest because an unfavourable relative price situation in regards to cereals may induce farmers to reduce the area under cereal crops and simultaneously induce them to allocate larger areas under pulse crops. Since the yield potential of pulse crops is much less than that of cereal crops and the requirement of inputs such as fertilizers, weedicides, pesticide and irrigation is relatively small, the change in the allocative decision of the farmers may result in decreased use of inanimate energy resources.

### d) Food Production and Requirements

One of the most important tasks the Government of India faces is providing enough food for the people. For a long time India has been dependent upon other countries to provide food for the people. The aspect of embarrassment aside, the mounting import bill erodes export earnings considerably.[1] During the past decades, one of the objectives of the government has been to attain self-sufficiency in food. The fact that most of the people are vegetarians must be taken into account. A vegetarian diet mainly consists of those items which are produced by the farmers in the agricultural sector-- cereal grains, pulses, vegetables, vegetable oil and spices.

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[1] "India in World Trade," Eastern Economist, Annual Number 1974, pp. 1380.

The strategy of achieving an increase in the productivity of human labour in the agricultural sector should be geared to meet the burgeoning food requirement in the country. This is an important aspect in that merely achieving an increase in the productivity of labour without any regard to the food requirement may prove frustrating. The introduction of soybeans in the agriculturally rich Terai region of the Uttar Pradesh State is a case in point. In terms of protein content and yield potential, this crop is superior to most pulse crops grown in India. It was thought that the problems of protein deficiency in the typical Indian diet and overall availability of pulses could be considerably alleviated by introducing this crop to Indian agriculture. Thus this approach was considered a step towards modernizing agriculture.

In spite of the problems of weeds and pests and the newness of technology, farmers of the Terai region were happy with the performance of this crop. But they faced a big problem in selling the soybeans as there were no buyers in nearby areas. As a result, despite the inherent advantages of the soybean crop, it has not become popular in the area.

The adoption of wheat gained momentum because its effects were of direct consequence to the well-being of farmers. There was no problem in selling the surplus produce and so the modernization process by way of adopting the new varieties of wheat was sustainable. That is the reason why the farmers' response to wheat crop was so overwhelming, especially in northern India.

## Summary

The inanimate resources play a significant role in exploiting the biological potential of the newly developed varieties of wheat and paddy.

However, indiscriminate use of the inanimate energy resources does not necessarily guarantee an increase in production. In the context of Indian agriculture, while some inanimate energy resources may prove to be highly productive, other may not be as productive. Knowledge about the role of each type of inanimate energy resource in terms of its productivity is of great significance espeically in the Indian economy where these resources are scarce and frequently must be imported. The other interfaces should also be taken into account in the planning process because they have important implications for both the modernization process and the Indian economy.

# CHAPTER V

# ECONOMIC ANALYSIS OF ENERGY RESOURCES IN CEREAL CROP PRODUCTION

Cereals are the most important constitutent of a typical Indian diet. The production of cereals is intimately related to food availability in the economy. Over the past two decades, the Government of India has had to import wheat in order to meet food requirements. The population of the country has been increasing by about 13 million every year. The production of cereal grains must receive priority and the cultivation of cereals must be modernized in order to enhance self-sufficiency. Such emphasis leads to a greater use of commercial energy resources.[1]

The availability of commercial energy resources is one of the most important aspects in the modernization of Indian agriculture. Commercial energy need is intertwined with food requirements. The productivity of commercial energy resources needs to be analysed. By doing so, the role of various types of inputs in increasing cereal food grain production can be determined. In the following an approach to this type of inquiry has been suggested.

## Model Formulation

In determining the role of commercial energy resources in the modernization of cereal crop cultivation, it is necessary to mention those items of investment which require a large proportion of the inanimate resources. The items of investment that have gained popularity in Indian agriculture are fertilizers, irrigation-pumps, wheat threshers, tractors, harrows, cultivators, weedicides and pesticides. Over the last two decades, the increases obtained in production of cereals have been attributed to such inputs.

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[1] See Lester R. Brown, Seeds of Change: The Green Revolution and Development in the 1970's (New York: Praeger Publishers, 1970), pp. 15-36, for a detailed discussion on changes such as the development of high yielding varieties, need for irrigation and changes in production performance.

Along with the increase in the use of commercial energy resources, the area under cereal crops has increased. The use of human labour in production of cereal crops has also increased. Hence, these three broad categories of factors of production have been increasing simultaneously over the last two decades. In as much as the present analysis of the significance of commercial energy resources is concerned, three items pertaining to commercial energy resources are particularly important: (1) fertilizers, (2) irrigation through pumps, and (3) tractors. The chief reason for excluding other items which also require commercial energy resources (such as tillers, threshers, etc.) is that their net contribution to output would appear to be relatively small in relation to other energy intensive inputs such as fertilizers and irrigation through pumps.

The aggregate production function for cereal food grains in India can be represented algebraically as follows:

$$Q_t = f(A,L,T,F,E,U) \qquad (1)$$

where:

$Q_t$ = Total production of cereal food grains (million metric tonnes),

A = Area devoted to cereal crops (thousand hectares),

L = Human labour engaged in agricultural production (million workers), T = Number of tractors in 30-50 h.p. range in a given year,

F = Quantity of fertilizer (nitrogen in thousand metric tonnes),

E = Electricity devoted to irrigated acreage (million kilowatt hours in a given year),

U = Error term.

## Choice of the Analytical Model

In view of the fact that there are many types of production functions, a brief discussion of the choice of production function for the present analysis is of importance.[1]

The types of production functions which are typically used in the analyses of agricultural production are: (1) quadratic, (2) square root, and (3) Cobb-Douglas. As well, a number of hybrid production functions such as the transcendental production function and the Balmukund production function have been developed. Each of these has a definite set of characteristics. The quadratic production function represents that type of input-output relationship in which output per unit of area increases over a certain range of input application, reaches a plateau, and declines as more input is applied to the given area. The square root production function represents a more or less similar type of output response. The Cobb-Douglas production function shows an asymptotic type of output response to input usage. The representation of marginal productivities differ from one type of production function to another. For instance, the marginal productivity curve is linear in the case of a quadratic function. The marginal product of a given input declines at a faster rate in the case of the quadratic function as compared with that of the square root function. The marginal productivity of an input declines in an asymptotic fashion if the input-output relationship is represented by the Cobb-Douglas production function.

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[1] An excellent account of various agricultural production functions is contained in Earl O. Heady and John L. Dillon, Agricultural Production Functions (Ames, Iowa: Iowa State University Press, 1961), pp. 1-73. See John L. Dillon, The Analysis of Response in Crop and Livestock Production (London: Pergamon Press, 1968), pp. 1-20, 31-32, for a rigorous and concise treatment of the analysis of production. See Paul H. Douglas, "The Cobb-Douglas Production Function Once Again: Its History, Its Testing and Some Emperical Values," Journal of Political Economy, Vol. 84, No. 5 (Oct. 1976), pp. 903-915, for a specific instance of this type of endeavour by one of the co-inventors of the Cobb-Douglas production function.

The transcendental logarithmic form of production function is preferred over the others in this study because it treats the output response associated with modern inputs such as fertilizer and irrigation in a more realistic fashion. For instance, use of fertilizer at the initial levels of application results in increasing marginal productivity. As more fertilizer is applied to a given area, the marginal product declines. Such changes in marginal products of an input cannot be represented through conventional production functions such as the Cobb-Douglas or quadratic variety.[1]

There is another reason which lends support to the use of the transcendental production function in this present study. While certain inputs such as fertilizers and water are directly absorbed by the plants, the remaining inputs help to create conditions in which plants can thrive.

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[1] For details see: Earl O. Heady and J.L. Dillon, Agricultural Production Functions (Ames, Iowa: Iowa State University Press, 1961), pp. 82-94. For an extensive discussion of the properties of transcendental logarithmic production functions, see: A.N. Halter, H.O. Carter and J.G. Hocking, "A Note on the Transcendental Production Function," Journal of Farm Economics, Vol. 29 (November 1957), pp. 966-974.

Evensen[1] discussed the need for grouping inputs into two categories. Following his approach the production process obtaining in agriculture can be represented algebraically as:

$$Q = f\ (fb\{xb, q^{b}\},\ fm\{Xm, q^{m}\}) \qquad (2)$$

where:

$Q$ = Total production of cereal foodgrains,
$xb$ = Biological inputs,
$Xm$ = Mechanical inputs,
$q^{b}$ and $q^{m}$ = Quality of unit vectors.

By "biological inputs", Evensen implies those inputs which are directly absorbed by the high yielding plant varieties; "mechanical inputs" refers to those inputs which are important in producing the crops, but whose main use pertains to creating conditions for plant growth and development. Increased use of biological inputs results in pronounced increase in crop output, especially in traditional agricultural production.

The transcendental logarithmic production function as indicated below is considered appropriate for the present analysis:

$$Q = A^{b1}\ T^{b2}\ L^{b3}\ \mathrm{exp}^{b4F + b5F^{2} \pm b6\ E}. \qquad (3)$$

With this functional form, it is possible to capture more adequately the influence of modern inputs such as fertilizer and irrigation on cereal output.

## Data

The data set consisted of time-series data on an all India basis for cereal food grain production, area devoted to cereal crops, human labour engaged in agricultural production, number of tractors of 30-50 horsepower range, quantity of nitrogenous fertilizers and electricity used for irrigation. The data were collected for the period 1956 to 1971 (Appendix B).

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[1] Robert Evensen, "The Green Revolution in Recent Development Experience," American Journal of Agricultural Economics, Vol. 56, No. 2 (May 1974), pp. 387-396.

At this stage, a note on the nature of the data is in order. The labour input variable is a proxy for labour use in cereal crop production as data on actual labour use in Indian agriculture is scanty. The fertilizer variable relates to the actual quantities of nitrogen used in various years. Nitrogen is by far the most important plant nutrient (see Chapter II). Tractors in the 30-50 horsepower range encompass the vast majority of tractors utilized in Indian agriculture. Good data on irrigation through electric pumps exist. The irrigation variable does not include irrigation using diesel pumps. Suitable data on irrigation using diesel pumps are not available.

## Results of Data Analysis

The following aggregate production function was estimated using the ordinary least square procedure.

$$Q = \underset{(7.75)}{A^{3.8064}} \; \underset{(-0.92)}{L^{-0.48595}} \; \underset{(-1.06)}{T^{-0.25945}} \; \text{Exp}^{\underset{(0.71)}{0.000201\,F} - \underset{(-1.51)}{.00000027F^2} + \underset{(1.9063)}{0.00024E}}. \qquad (4)$$

$R^2 = 0.98$

$DW = 2.93$

NOTE: Figures in the parenthesis are 't' ratios of the respective coefficients.

The results consist of three statistical measures. They are (1) the coefficient of multiple determination, (2) the Durbin-Watson statistic and (3) 't' ratios. While values of the first two are of direct significance to the general validity of the model, the values of the last measure (i.e., the 't' ratios of the individual variables) pertain to the significance of the explanatory power of the independent variables included in the regression model.

The value of the coefficient of multiple determination was 0.98. This value indicates that the degree of association between the two sets of variables (i.e., independent and dependent variables) was very high. The extent of variation in the dependent variable explained by the independent variables is 98 percent.

The Durbin-Watson statistic for the regression model was 2.93. It was larger than the upper boundary table value of 2.10. This implies that there is no positive auto-correlation within the columns of observation pertaining to each of the independent variables included in the model. The regression model conforms with the statistical requirements of validity for further inference.

As to the level of significance, coefficients of only three variables (i.e., area devoted to cereal food grain production, the squared fertilizer term and electricity devoted to irrigation) were significantly different from zero. While area under cereal crops, and electricity for irrigation are significant at the 5 percent level of probability, the fertilizer variable (only the squared term) is significant at 10 percent. The fact that the non-squared fertilizer term (F) is not statistically significant is somewhat unexpected and may have been due to possible existence of multi-collinearity between F and $F^2$ or between F and the irrigation variable. The other variables (i.e., number of tractors, human labour) are not significant. It is perhaps not surprising that the coefficient associated with the tractor variable is not significant because the role of tractors in Indian agriculture as a whole is relatively minor at this stage of development. The increase in the number of tractors has largely occurred in the wheat zone of northern India where agricultural modernization and tractorization are pronounced.

## Economic Implications of Results

The main focus of interest in this study was to determine the role of various commercial energy resources whose agricultural use has been increasing during the past two decades. The results indicate that increased use of fertilizers and irrigation may result in increased production of cereal food grains in India. Application of these inputs is lower than the recommended rates in most of the regions of India. Part of the reason for the gap between actual and recommended rates of application of these inputs is the shortage of power and, at times, the lack of supplies of fertilizers in many areas. The supply of these inputs, therefore, should be a vital part of the strategy for agricultural modernization in India.

Nothing conclusive can be said about the significance of tractor use in increasing cereal food grain production. However, it is suggested that studies on the significance of tractor use in Indian agriculture should be encouraged by the government and research oriented institutions.

# CHAPTER VI

# ECONOMIC IMPLICATIONS OF TRACTOR USE FOR ANIMATE ENERGY RESOURCES

In the preceding chapter it was observed that while the use of fertilizer and irrigation resulted in a significant increase in cereal food grain production, the use of tractors did not. This finding warrants serious consideration in that it is contradictory to the existing view on the role of tractors in the Indian economy. This view suggests that use of tractors results in a significant increase in farm output.[1]

In India, the number of tractors has been increasing. Since tractor use involves consumption of diesel fuel, increases in the number of tractors will result in an increased dependence on diesel fuel, which is procured largely through imports. The use of tractors displaces animate energy resources (i.e., human labour and bullock power). Employment opportunities for displaced persons from the agricultural sector are very limited in the Indian economy. Therefore, tractor use has a two-pronged implication for the agricultural sector of India.

## Objectives

The general objective of this chapter is to present the economic implications of tractor use in Indian agriculture. This task was accomplished by analyzing specific instances of tractor use in cultivation of important crops such as wheat, maize and paddy. This chapter examines:

1. The extent to which wheat, maize and paddy crops respond to

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[1] National Council of Applied Economic Research, Impact of Mechanization in Agriculture on Employment (New Delhi: National Council of Applied Economic Research Press, 1973), pp. 5-10. S.S. Grewal and A.S. Kahlon, "Impact of Tractorisation on Draft Animals," Agricultural Situation in India (February 1973), p. 735.

successive increases in the intensity of tractor use in their cultivation, and

2. The employment potential of tractors in cultivation of these crops.

## Materials and Methods

Since the main thrust of the study revolves around various types of energy use and their significance in the modernization of Indian agriculture, it is necessary to clarify the nature of data through which the problem has been treated in the sections that follow. As for the measurement of various forms of inputs in terms of energy use, at least one of two approaches has been made by various researchers. The approaches are (1) gross energy embodied in a particular resource which is wholly or partially put into farm operation, and (2) useful energy developed with a particular equipment in performing farm operations.

The concept of useful energy has been utilized in the analysis of energy relations and energy productivity. The reason the concept of useful energy is preferred over "gross energy expenditure" is because the latter does not differentiate between the energy of an employed worker and that of an unemployed worker. For instance, consider two persons, x and y. Further, x is gainfully employed and works in his field every day for eight hours and y is unemployed. Both of them consume an equal quantity of food, say 12,558 kilojoules per day. Following the "gross energy expenditure" method, the per hour kilojoule expenditure for x is 1,570. By the same argument, the per hour kilojoule expenditure of y is also 1,570. Thus the "gross energy expenditure" method does not differentiate between the employed and unemployed labour force and this is the reason why the concept of useful energy has been emphasized here.

The data for analysis were obtained from experiments conducted during 1973-74 at the G.B. Pant University of Agriculture and Technology, Pantnagar, Nainital (Northwest U.P.), India. The experiments were conducted using wheat, maize and paddy. Each crop was subject to four treatments in order of increasing levels of tractor power or decreasing levels of human labour and bullock power. Each of the experiments was set up in a randomized block. Description of each treatment is given below:

T1 = Tillage operations performed with bullock power and indigenous implements.

T2 = Tillage operations performed with bullock power and improved implements,

T3 = Tillage operations performed by a 20 horse power tractor and matching implements, and

T4 = Tillage operations performed by a 35 horse power tractor and matching implements.

Each treatment was subjected to four replications in order to minimize residual errors due to fertility differentials. The size of each plot was 0.5 hectare for wheat and 0.10 hectare for maize and paddy.

Except for variations in treatments, a uniform level of various inputs such as seed rate, quantity of nutrients (viz., nitrogen, phosphoric acid, potash and zinc sulphate), and frequency of irrigation was maintained in each plot of the experimental field. The most popular variety of each crop was selected for the experiment-- RR21 for wheat, Ganga 5 for maize, and IR24 for paddy. Results of the experiments are as presented in

Tables 6.1, 6.2 and 6.3.[1]

## TABLE 6.1

## EFFECT OF VARIOUS SOURCES OF POWER ON PER HECTARE YIELDS OF WHEAT, MAIZE AND PADDY

| Crop | T1 | T2 | T3 | T4 |
|---|---|---|---|---|
| | | (Quintals[1] per Hectare) | | |
| Wheat | 38.26 | 37.18 | 38.42 | 35.48 |
| Maize | 29.37 | 29.01 | 27.95 | 34.66 |
| Paddy | 40.51 | 38.05 | 45.43 | 44.37 |

[1] In India, a quintal consists of 100 kilograms.

## TABLE 6.2

## ENERGY EXPENDITURE PER HECTARE AT DIFFERENT LEVELS OF MECHANIZATION IN CULTIVATION OF WHEAT, MAIZE AND PADDY CROPS

| | Treatments | | | |
|---|---|---|---|---|
| Crop | T1 | T2 | T3 | T4 |
| | | (Energy in Kilowatt-Hours) | | |
| Wheat | 561.74 | 522.14 | 550.41 | 694.01 |
| Maize | 348.56 | 316.37 | 376.22 | 432.40 |
| Paddy | 548.74 | 533.76 | 676.52 | 640.60 |

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[1] Data were made available through the courtesy of R.L. Singh and S.P. Kulshrestha of the Departments of Agronomy and Agricultural Engineering, G.B. Pant University of Agriculture and Technology, Pantnagar, Nainital, (U.P.), India.

## TABLE 6.3

## DISTRIBUTION OF ENERGY FROM DIFFERENT SOURCES OF POWER FOR WHEAT, MAIZE AND PADDY CROPS

| Crop | Source of Energy | Distribution of Energy by Treatment | | | |
|---|---|---|---|---|---|
| | | T1 | T2 | T3 | T4 |
| | | (Energy in Kilowatt-Hours per Hectare) | | | |
| Wheat | Electrical | 123.59 | 125.31 | 115.59 | 124.93 |
| | Mechanical | 213.46 | 219.30 | 335.75 | 464.98 |
| | Bullock | 106.73 | 73.10 | 0 | 0 |
| | Human | 117.96 | 104.43 | 99.07 | 104.10 |
| TOTAL | | 561.74 | 552.14 | 550.41 | 694.01 |
| Maize | Mechanical | 198.77 | 186.66 | 274.64 | 332.98 |
| | Bullock | 45.27 | 25.31 | 0 | 0 |
| | Human | 104.52 | 104.40 | 101.58 | 99.44 |
| TOTAL | | 348.56 | 316.37 | 376.22 | 432.42 |
| Paddy | Electrical | 241.46 | 240.21 | 243.55 | 243.44 |
| | Mechanical | 71.33 | 69.38 | 317.96 | 281.86 |
| | Bullock | 115.23 | 101.41 | 0 | 0 |
| | Human | 120.72 | 122.76 | 115.01 | 115.30 |
| TOTAL | | 548.74 | 533.76 | 676.52 | 640.60 |

## Hypotheses Formulation

In as much as the problem is concerned with the economics of modernization through the use of mechancial appliances in farm operation and impending energy scarcity due to it, two hypothese are developed here. They relate to two different areas of concern (i.e., crop output response to tractor use and direct labour employment in agriculture).

Increase in food grain production in India has been partially attributed by some observers to the increase in the number of tractors. This implies that crop output responds positively to tractor use. While this could be true of certain crops, this is not tenable in general. The first area of concern, therefore, is to determine whether the output of crops such as wheat, maize and paddy respond positively to tractor use within a given cropping season.

The other area of interest is related to the direct effects of tractor use on employment of human labour and bullock power. Results of studies pertaining to the economics of employment and energy needs in Indian agriculture suggest that more employment is generated on tractor owning farms. This may arise because tractor use facilitates multiple cropping--the growing of two or more crops per year on the fields of the tractor owner. Since tractors are largely used for tillage purposes and tractor owners enter into custom tilling, the direct effects of tractor use on displacement of human labour and bullock power in a given area are important. The relevant hypothesis is that the direct effects of tractor use in the cultivation of certain crops are "labour displacing " rather than "employment generating". Given the data available for analysis the two hypotheses can be tested only with respect to tillage operations and cropping season, not yearly operations.

## Model Formulation

### The Hypothesis of Positive Crop Response to Tractor Power

The model for positive response to mechanical energy from tractors can be put algebraically in the following manner.

$$Y = f(Em/Ec, Ee, S; u) \qquad (1)$$

where:

Y = Output per hectare of a given crop,
Em = Mechanical energy,
Ec = Chemical energy contained in fertilizers, pesticides, weedicides, zinc sulphate,
Ee = Electrical energy for irrigation, threshing and winnowing,
S = Seed rate per hectare, and
u = Error term.

On the right hand side of the expression, factors such as Ec, Ee, S, are held constant and only Em is varied.

Since the main interest of the study is to determine the response behaviour of crops to mechanical energy in the event that tractor power input is increased, use of a simple linear regression equation is appropriate for the analysis.

$$Y = a + bEm \qquad (2)$$

where:

a = Constant term,
b = Coefficient associated with mechanical energy.

## The Hypothesis of Employment or Unemployment Generation Potential

The main concern here is to determine the magnitude and direction of change in human labour and bullock power when the proportion of tractor power is increased in the tillage operations. If the direction is positive and magnitude is significant due to increased use of tractor power, it will provide adequate grounds to designate the modernization process as "employment generating". If the reverse is true, the process will be designated as "labour displacing" or "unemployment creating". We are therefore concerned with the type of relationship that exists between the two kinds of energy resources required in tillage operations (viz., animate and inanimate energy resources). Hence the above statistical method (viz., linear regression model) is appropriate for the analysis. The relationship can be stated algebraically as:

$$Ea,m = f(Ei,m, u) \qquad (3)$$

where:

Ea,m = Energy drawn from human labour and bullock power in per hectare cultivation of a crop,

Ei,m = Energy drawn from tractor in per hectare cultivation of a crop,

u = Error term.

The functional form of algebraic expresion (3) is:

$$Ea,m = a \pm bEi,m \qquad (4)$$

where:

a = Constant term, and

b = Coefficient associated with inanimate energy.

From expression (4) inferences can be made in the following manner. If the coefficient associated with the variable Ei,m (i.e., energy drawn from tractor) is positive and is significantly different from zero, the strategy for modernization through mechanization will be designated as "employment generating". If the coefficient is positive but not significantly different from zero, the strategy is "employment neutral". On the other hand, if the coefficient is negative and is significantly different from zero, the strategy will be designated as "labour displacing". Further, if the coefficient is negative but is not significantly different from zero, the strategy is "employment neutral". In the following, the employment implications of modernization in tillage operations through tractor use are summarized.

TABLE 6.4

EMPLOYMENT IMPLICATIONS OF A STRATEGY

| Status of Coefficient | Sign of Coefficient | |
|---|---|---|
| | Positive | Negative |
| Significant | Employment Generating | Employment Displacing |
| Non-Significant | Employment Neutral | Employment Neutral |

## Results and Discussion

### Crop Output Response to Tractor Use in Tillage Operation

With respect of each crop (i.e., wheat, maize and paddy), a linear regression equation of the form presented in expression (2), was fitted to the data in order to examine the relevance of the "positive crop response to tractor power" hypothesis. Results are presented in Table 6.5.

TABLE 6.5

RESULTS SHOWING RESPONSE OF CROPS
TO INCREASING USE OF TRACTORS

| Crop | Value of Constant Term | Coefficients | T-Value of the Coefficient | $r^2$ |
|---|---|---|---|---|
| Wheat | 45.94284 | -0.01470 | -1.868 | 0.6361 |
| Maize | 12.67403 | +0.04770 | +1.770 | 0.6106 |
| Paddy | 13.30125 | +0.04798 | +6.206 | 0.9506 |

Wheat-- The explained variance in output due to energy use is not significantly different from zero. The sign of the coefficient is negative and the coefficient is not significantly different from zero. Nothing conclusive can be said about the relationship between wheat yields and tractor use in tillage operations. The hypotheses of positive crop response to tractor use in tillage operations does not qualify the statistical test and is rejected in the case of wheat crop.

Maize-- Although the sign of the coefficient associated with the inanimate energy (i.e., 0.04770) is positive, it is not significantly different from zero. The statistical results do not conform to the "positive response hypothesis" with regard to maize.

Paddy-- The coefficient associated with the energy variable is positive, and the value of $r^2$ is 0.9506. The t value, 6.206, suggests that it is significantly different from zero. It can be generalized that there exists a significant relationship between the rate at which mechanical energy is applied in the farm operation and paddy yields. The results conform to the "positive response hypothesis". Existence of this kind of relationship suggests that tillage operations are important in the cultivation of paddy crop and paddy yields can be considerably increased, provided that an adequate number of tillage operations are ensured.

## Direct Effect of Tractor Use on Employment of Animate Energy in a Cropping Season

For the determination of the employment potential of a modernization process based upon progressive tractor use, three crops were selected. The regression model, as expressed in equation (4) was fitted to data pertaining to each crop. For this purpose data presented in Table 6.3 were utilized. Further, the results so obtained are presented in Table 6.6.

The direction and magnitude of the coefficients associated with the inanimate energy variable are of particular interest in this study. The negative sign associated with the above variable indicates that increased use of tractor power will have serious implications for the employment of human labour and bullock power in cultivation of wheat, maize and paddy crops. The in-season employment implications of tractor use in tillage operations of each crop are discussed below.

Employment Implications of Mechanization in Wheat-- The coefficient

## TABLE 6.6

## REGRESSION RESULTS FOR DISPLACEMENT OF HUMAN LABOUR AND BULLOCK POWER DUE TO TRACTOR POWER

| Crop | Value of Constant Term | Coefficients | T-Value of Coefficient | $r^2$ | Displacement Elasticity |
|---|---|---|---|---|---|
| Wheat | 283.729 | -.4293 | -2.19 | .7054 | -.8746 |
| Maize | 195.922 | -.3052 | -2.46 | .7512 | -.6305 |
| Paddy | 259.951 | -.5156 | -3.91 | .8843 | -.5059 |

with the independent variable attained a value of -.4293 and its associated 't' value is -2.19 (i.e., significant at 5 percent level of probability). Since the coefficient is negative and statistically significant from zero, the mechanization process in wheat is "labour displacing".

As for energy relations, the elasticity of displacement of human labour and bullock power due to use of tractor power was computed (last column, Table 6.6). Computation of the displacement elasticity as such appears to be one of the most important aspects of the economics of energy use in agriculture in that a high negative value with respect to a particular crop will suggest the possibility of substitution of tractor power for human labour and bullock power. The magnitude of the elasticity is -.8746. It suggests that for a percentage increase in energy from tractor power in the factor mix, energy from human labour and bullock power will be displaced by .88 percent.

The employment implications of tractor use in cultivation of wheat can be further elaborated using the coefficient associated with inanimate energy (Table 6.6). For this purpose we need to define hourly release of energy when a plough unit (one man and two bullocks) is engaged in ploughing operations. A plough unit discharges 666 kilocalories of useful energy per hour, (i.e., 32 kilocalories per man per hour + 2(317 kilocalories per bullock per hour). Provided that a plough unit operates for 8 hours per day, the release of energy in ploughing operation is 5,344 kilocalories. The net release of useful energy from a 35 horsepower tractor is 21,000 kilocalories (i.e., 35 x 600 kilocalories) per hour. In view of the fact that the value of the coefficient for inanimate energy is -.4293, the net energy release per hour from a 35 horsepower tractor is equivalent to the 9,015 kilocalories of human labour and bullock power required in ploughing. In other words, one hour of tractor operation in ploughing will displace 1.7 plough units or will render a plough man and 2 bullocks unemployed for 1.7 days.

A brief discussion of the conditions of production obtaining in India is necessary. First, the farmers with relatively large land holdings provide employment to the rural labour force. Secondly, the cities are no longer centers of employment for the rural labour force. Thirdly, there has been a rapid growth in the number of tractors in India, albeit from a small base. The total number of tractors increased from 39,603 in 1965 to 143,000 in 1971 and to 170,000 in 1974.[1] The tractor owners also perform custom services in their surrounding areas, and on average, a tractor is put into use for 1,200 hours per year.[1] A 35 horsepower tractor has a displacement potential of 2,040 plough units (i.e., 2,040 working man days and 4,080 bullock days) annually in a wheat growing region. On average, an agricultural worker works for 240 dyas[2] a year. Thus, the displacement potential in terms of number of agricultural workers is estimated at 8.5. The in-season effects of tractor use in tillage operations in wheat are high. In the absense of alternative employment opportunities in the rural areas, increases in the number of tractors will result in deterioration of the economic well-being of displaced persons.

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[1] FAO, Production Yearbook, Vol. 28, No. 1 (1974), pp. 256.

Employment Implications of Mechanization in Maize-- The sign of the coefficient associated with tractor power is negative. Tractor use for tillage operations in maize is "labour displacing". The value of the coefficient associated with inanimate energy is -.3053. It suggests that an increase of one kilowatt-hour of inanimate energy will result in a decrease of .3053 kilowatt-hours of animate energy. In other words, one hour of work performed by a 35 horsepower tractor will displace 6,412

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[1] The annual number of working hours of a tractor varies from farm to farm and from one area to another. Generally, the tractors are put into use for more than 1,000 hours per year. A tractor is used to perform a number of activities such as seeding, planking, ridge-making, and hauling the farm produce to grain marketing centers, in addition to tillage operations. The assumption of 1,200 hours of annual work by a tractor in this study does not include such activities. Thus tractor use in tillage may appear to be on the high side. However this assumption does not overstate the question of net displacement of animate energy in agriculture because the impact of the tractor use on net displacement of animate energy in non-tillage activities is quite pronounced.

[2] The period of employment of an agricultural worker in a year is estimated at 240 days. See: Raj Krishna, "Measurement of the Direct and Indirect Employment Effects of Agriculture with Technical Change," in Earl O. Heady and L.R. Whiting, Externalities in Transformation of Agriculture: Distribution of Benefits and Costs from Development (Ames: Iowa State University Press, 1975), pp. 305-327.

(i.e., 21,000 x .3053) kilocalories of animate energy. Further, 6,412 kilocalories of energy is equivalent to 1.2 plough units. Assuming that a tractor is put to work for 1,200 hours in a year, the net displacement of plough unit days is 1,440 (i,e., 1,440 man days and 2,880 bullock days in a year). Since on average an agricultural worker is employed for 240 days, 6 persons will be displaced by one tractor.

Employment Implications of Mechanization in Paddy-- The coefficient associated with tractor power is negative. Its value is -.5156. The coefficient is significantly different from zero. The "displacement elasticity" in the case of paddy is -.5059. The modernization process through tractor use in cultivation of paddy crop, therefore, is "labour displacing".

Since the value of the coefficient is -0.5156, 21,000 kilocalories of energy derived from a tractor is equivalent to 10,828 kilocalories of energy from human labour and bullock power. The total number of hours required by a plough unit to release 10,828 kilocalories of energy is estimated at 16.26..The total number of days required by a plough unit to perform the same amount of work done by a 35 horsepower tractor in one hour is approximately 2 days (2.03 days). On this basis, if a tractor is gainfully employed for 1,200 hours in a year in a paddy growing region, it will displace about 2,400 plough units (i.e., 2,400 man days and 4,800 bullock days). The displacement potential of a tractor in a year, expressed in terms of number of agricultural workers, is 10.

## Limitations

The discussion of displacement of animate energy due to tractor use should be noted with caution. The estimates of displacement presented in this study relate to the direct and in-season effects of tractor use in cultivation of wheat, maize and paddy crops. These estimates are not tenable for generalizaton on tractor owning farms. On such farms tractor use facilitates multiple cropping and therefore displacement of human labour may not appear significant. However, discussion of indirect effects of tractor use on the tractor owning farms is outside the scope of this study because of the paucity of data.

# CHAPTER VII

## RELATIVE MODERNIZATION: A CASE STUDY OF ENERGY USE ON RELATIVELY MODERNIZED AND NON-MODERNIZED FARMS OF MUZAFFARNAGAR DISTRICT OF UTTAR PRADESH

In the foregoing chapters, the problems and prospects of agricultural modernization have been discussed in relation to the availability of commercial energy resources and the impact of their use on the employment of animate energy resources. These aspects are highly aggregative in that each of them concerns energy use for the entire agricultural economy. The models developed in the preceding chapters did not include aspects such as the feasibility and effects of modernization on the individual farms in India. Problems of unemployment and low productivity are overwhelming in Indian agriculture. The stragtegy of modernizing Indian agriculture should achieve increases in the productivity of resources and in the level of employment. Under these circumstances, emphasis on achieving relative modernization may prove to be an appropriate strategy. The concept of relative modernization encompasses increased use of inanimate energy inputs such as fertilizers and irrigation, use of intermediate technology, and seeding proportionately large areas with the high yielding varieties of crops. This chapter examines the effects of such modernization on energy use as well as the economic efficiency of important resources in the cultivation of wheat crops on the farms of the Muzaffarnagar District of Uttar Pradesh State. Although this district is moderately advanced, it is certainly less advanced than most districts in Punjab. The data base for Muzaffarnagar District which has been utilized pertains to the agricultural year 1966-67, the year in which the new varieties of wheat were beginning to be adopted in Northern India.

In order to examine changes in the productivity of energy resources due to modernization two sets of data are required. While one set of data should relate to the conditions of relatively modernized farms, the other set should relate to relatively non-modernized farms. This was an important requirement of the study. In order to perform a comparative analysis of energy efficiency in wheat production, this classification procedure was considered necessary.

This chapter is divided into four sections:

1. Selection of a suitable area,
2. Evolving modernization characteristics of the farms of the area,
3. Grouping of the farms according to modernization characteristics, and
4. Determining the efficiency of energy resources in wheat cultivation on the modernized and non-modernized farms.

## Selection of a Representative Area

The State of Uttar Pradesh presents an average picture of the Indian economy. There are various reasons for making this type of assertion. Firstly, like the other states, agriculture is its mainstay. Secondly, the growth of agriculture in this region has been modest in comparison with the states of Punjab, Haryana, Gujarat, Tamil Nadu, Karnataka and Himachal Pradesh.[1] The other aspects of the agricultural economy of this state are similar to those in other parts of the country. Average per capita income in the country during the late sixties was Rs 551 while it was Rs 480 in Uttar Pradesh State (Table 7.1). The density of population is relatively higher than that of the entire country.

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[1] For the period 1952-53 to 1964-65, the average growth rate of agricultural production for the entire country was estimated at 3.42 percent by the Ministry of Food and Agriculture. For Uttar Pradesh State the growth rate was estimated as 1.82 percent. For details see: R.N. Tewari, Agricultural Development and Population Growth (Delhi: Sultan Chand and Sons, 1970), pp. 24-28.

The economic characteristics of the agricultural sector in Uttar Pradesh are more or less similar to the average economic characteristics of the entire country. For instance, the percentage of arable land in the state is 58 percent compared to 46 for the entire country; the per hectare value of agricultural produce was Rs 1,237.00 as against the average value of Rs 992 for the entire country. The annual increase in the production of the food grains for the years 1961-62 to 1973-74 was 1.7 percent whereas it was 2.1 for the entire country.

The Muzaffarnagar District of Uttar Pradesh State is a useful district to study. The per capita land availability in the rural areas of this district is less than that of the entire state.[1] Further, agriculture is the mainstay for the people of this district. As for modernization, the farmers in the district have responded favourably to adoption of the new wheat technology.[2]

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[1] Prof. R.N. Tewari has classified the entire state into five regions on the basis of physiography, density of population and general economic conditions. They are (1) Himalayan region, (2) Western region, (3) Bundelkhand region, (4) Central region, and (5) Eastern region. Of all the regions, the Western region is by far the most prosperous and agriculturally advanced. In the Muzaffarnagar District, the per capita land availability in the rural areas is 0.7 acres which is on the lower end of the scale. See: Ibid., Appendix 1:1:1.

[2] See Roshan Singh, The Social and Economic Implications of the Large Scale Introduction of High Yielding Varieties in Food Grains (Wheat) in Muzaffarnagar District (Agra: Raja Balwnant Singh College, 1973), p. 15.

## TABLE 7.1

## A REGIONAL PROFILE OF INDIA

| Region | Area ('000 Sq.Km) | Population (million) 1971 | Density (Person Per.Sq. Km).1971 | Average Rainfall (cm) | Cultivated Area as Per-cent of Geographical Area. 1970-71 | Per Hectare Value of Agricultural Production (Rs) 1969-70 |
|---|---|---|---|---|---|---|
| Uttar Pradesh | 294 | 88.3 | 300 | 117 | 58 | 1,237 |
| Bihar | 174 | 56.4 | 324 | 132 | 49 | 990 |
| Maharashtra | 308 | 50.4 | 164 | 106 | 60 | 652 |
| West Bengal | 88 | 44.3 | 504 | 174 | 63 | 1,754 |
| Andhra Pradesh | 277 | 43.5 | 157 | 90 | 43 | 1,028 |
| Madhya Pradesh | 443 | 41.7 | 94 | 123 | 42 | 642 |
| Tamil Nadu | 130 | 41.2 | 316 | 97 | 47 | 1,396 |
| Karnataka | 192 | 29.3 | 153 | 104 | 54 | 883 |
| Gujarat | 196 | 26.7 | 136 | 81 | 51 | 842 |
| Rajasthan | 342 | 25.8 | 75 | 46 | 45 | 450 |
| Orissa | 156 | 21.9 | 141 | 153 | 39 | 915 |
| Kerala | 39 | 21.3 | 549 | 267 | 56 | 2,174 |
| Assam | 79 | 14.6 | 186 | 241 | 29 | 1,868 |
| Punjab | 50 | 13.5 | 269 | 64 | 81 | 1,504 |
| Haryana | 44 | 10.0 | 227 | 76 | 81 | 1,087 |
| Jammu & Kashmir | 222 | 4.6 | - | 102 | 16 | 1,429 |
| Himachal Pradesh | 56 | 3.5 | 162 | 184 | 11 | 1,110 |
| Tripura | 11 | 1.6 | 149 | 193 | 23 | 2,119 |
| Manipur | 22 | 1.1 | 48 | 193 | 8 | 1,702 |
| Meghalaya | 23 | 1.0 | 45 | 241 | 7 | - |
| Nagaland | 17 | 0.5 | 31 | 193 | 7 | - |
| Sikkim | 7 | 0.2 | 27 | - | - | - |
| All India | 3,281 | 548 | 178 |  | 46 | 992 |

Source: Commerce Research Bureau "Water in the Indian Economy" Commerce Vol. 131, No. 3372 (Annual Number 1973), pp. 279-291.

(con't).

## TABLE 7.1 (Con't)

## A REGIONAL PROFILE OF INDIA

| Region | Growth Rate of Production of Food Grains. Annual Rate of Increase Between 1961-62 & 1973-74 | Per Capita State Income at Current Prices (Rs) Average of 1967-68 to 1969-70 | Percentage of Net Area Irrigated in 1970-71 by: | | | |
|---|---|---|---|---|---|---|
| | | | Canal | Tanks | Wells | Others |
| Uttar Pradesh | 1.7 | 480 | 48 | 34 | 15 | 3 |
| Bihar | 1.7 | 409 | 38 | 8 | 25 | 29 |
| Maharashtra | -2.2 | 636 | 22 | 16 | 57 | 5 |
| West Bengal | 2.5 | 667 | 65 | 20 | 1 | 14 |
| Andhra Pradesh | 1.0 | 537 | 48 | 34 | 15 | 3 |
| Madhya Pradesh | 1.1 | 458 | 48 | 9 | 38 | 5 |
| Tamil Nadu | 2.3 | 558 | 34 | 35 | 30 | 1 |
| Karnataka | 3.0 | 552 | 37 | 32 | 23 | 8 |
| Gujarat | 4.2 | 667 | 17 | 2 | 80 | 1 |
| Rajasthan | 1.7 | 455 | 35 | 13 | 51 | 1 |
| Orissa | 1.5 | 488 | 23 | 51 | 4 | 22 |
| Kerala | 2.1 | 555 | 49 | 17 | 1 | 33 |
| Assam | 2.5 | 581 | 63 | | | 37 |
| Punjab | 6.5 | 940 | 45 | | 55 | |
| Haryana | 4.6 | 810 | 62 | | 38 | |
| Jammu & Kashmir | 4.1 | 426 | 98 | | 2 | |
| Himachal Pradesh | 9.0 | 585 | | | 1 | 99 |
| Tripura | 4.6 | 532 | | | | 100 |
| Manipur | 5.4 | 458 | | | | 100 |
| Meghalaya | 1.0 | | | | | 100 |
| Nagaland | 4.0 | 420 | | | | 100 |
| Sikkim | | | | | | |
| All India | 2.1 | 551 | 40 | | 38 | 8 |

The district lies between 29° 11' and 29° 45' latitude and between 77° 4' and 78° 7' east longitude. The total geographical area of the district is 435,000 hectares. The population of the district is nearly one million. Its mean height above sea level is 240 meters. The rivers Ganges and Yamuna form the eastern and western boundaries of the district, respectively (see Figures 4 and 5).

The district has a typical monsoon climate. There are three distinct seasons in a year (i.e., rainy, winter and summer). The rainy season commences on the last week of June and lasts until the second week of October. The winter season begins after the rainy season and lasts until March and the remaining months constitute the summer season. The average annual rainfall of the district is 80 centimeters, a large part of the precipitation taking place during the rainy season.

The rainy and winter seasons are the periods of intense agricultural activity and with the onset of each season, seeding of various kinds of crops begins.[1] These seasons are commonly known as the Kharif and Rabi seasons. During the Kharif season, crops such as paddy, maize, moong, sorghum, bajra, etc. are grown, whereas during the Rabi season, wheat, barley, chick peas, peas, lentils, etc. are grown.

## Characteristics of Agricultural Modernization in Muzaffarnagar District

The necessity of discussing modernization characteristics for a given region arises because of the fact that the scope of modernization in any region is dependent upon the region's resources and the manner in which these resources are allocated in the production of various items.

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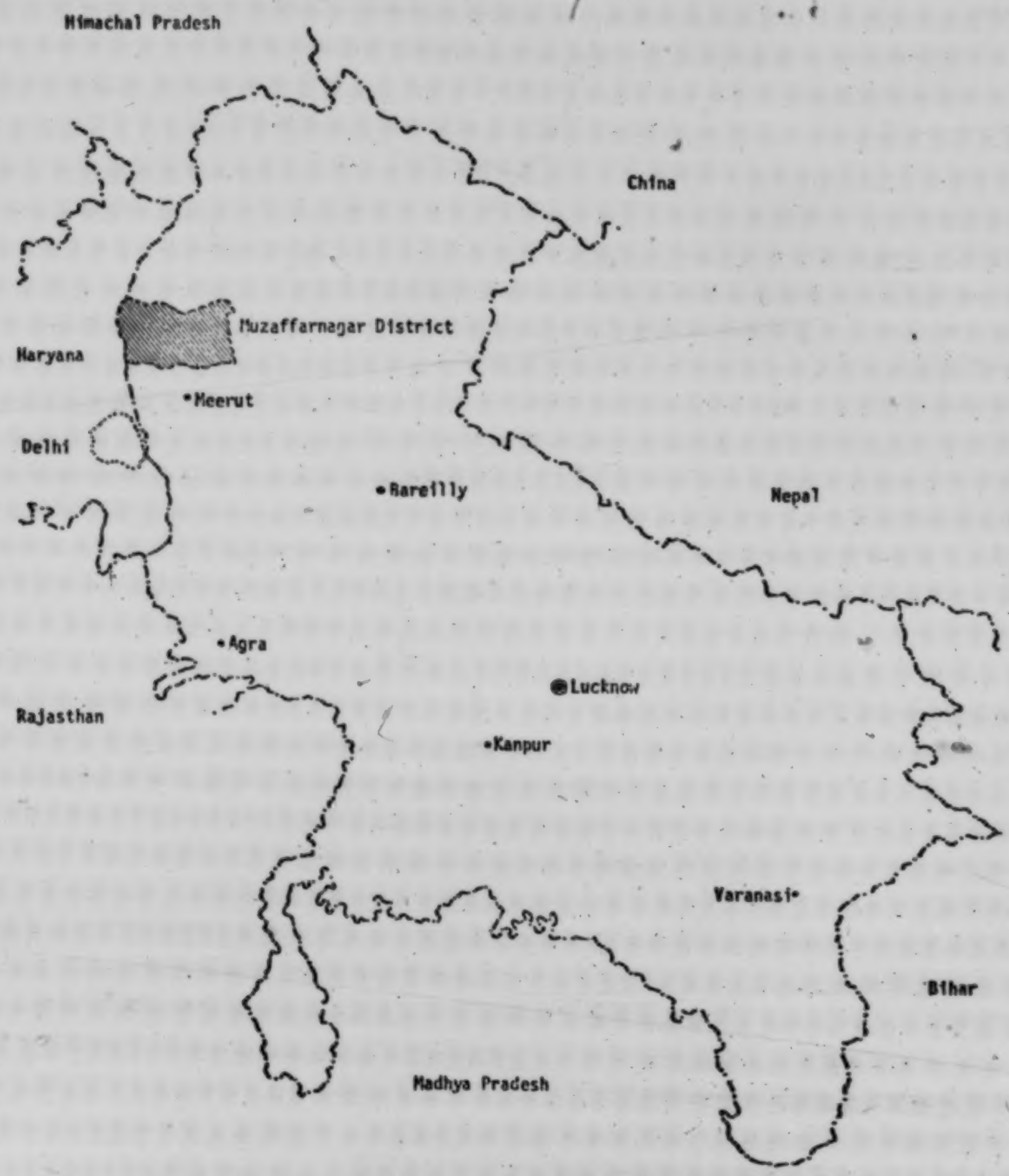
[1] *Ibid*., pp. 6-9.

FIGURE 4

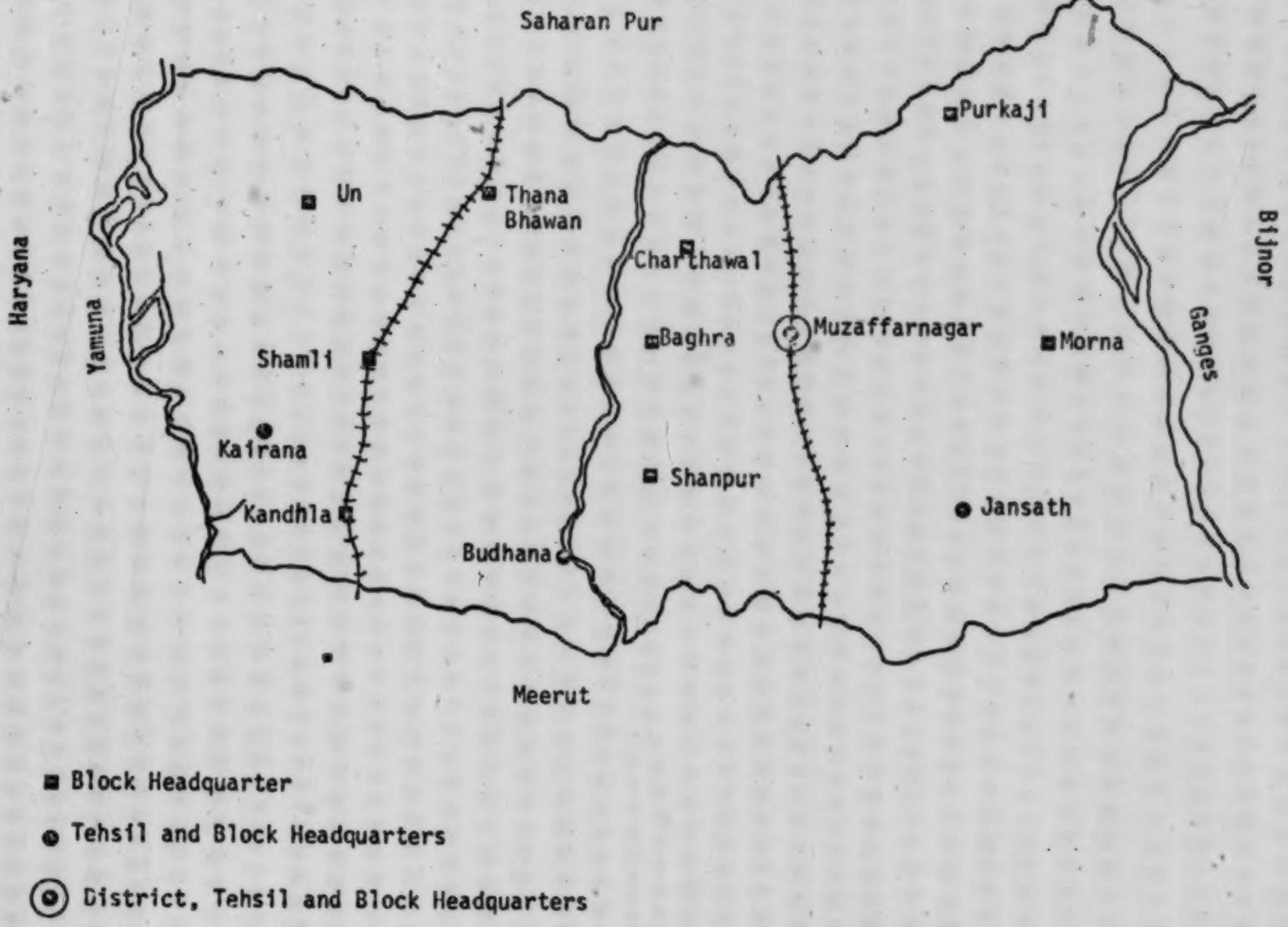
Map of Uttar Pradesh Showing
the Muzaffarnagar District



Source: J.P. Chaturvedi, States of Our Union: Uttar Pradesh (New Delhi: Publications Division, Ministry of Information and Broadcasting, Government of India, 1970), Appendix II.

FIGURE 5

Map of Muzaffarnagar District



In other words, one needs to examine the patterns of production, distribution and resources (the main areas of economic activity), carefully in order to suggest the modus operandi for modernization of a given region.

The Muzaffarnagar District is primarily an agricultural region. The size of land holdings varies from .28 hectares to 25 hectares, although the proportion of the larger land holdings is very small. Wheat is the most important crop of the area. The chief source of power in the fields is the bullock.

The scope of modernization is directly dependent upon the manner in which resources are put into use for agricultural production. As a farm unit progresses towards modernization, certain economic features emerge which are different from those of a farm unit which is non-modernized or traditional. In discussing modernization characteristics, however, a basic frame of reference (i.e., the traditional or non-modernized unit) was required.

The use of inputs such as fertilizers, irrigation, weedicides, pesticides and improved seeds is very limited on a "traditional farm". The means of production are limited to wooden ploughs, picks and sickles. Mostly those crops which can thrive well under poor moisture conditions are grown. The produce is stored in dwelling houses and the land holding is fragmented in three or more plots. Having defined the traditional farm, the integral parts of agricultural modernization will be examined.

### Per Acre Expenditure on Fertilizer

It is reasonable to assume that on a progressive farm fertilizer is used in cultivation of high yielding varieties of crops. The yardstick for a modernized farm is estimated at Rs 30.00 per acre, on the basis of the fact that only a part of the entire acreage is allocated toward crops requiring fertilizer. An investment of Rs 30.00 per acre will elicit a significant difference in production performance compared to areas where farmers invest smaller sums or none at all on fertilizers.

## Per Acre Expenditure on Irrigation

Irrigation is one of the most important inputs in the cultivation of high yielding varieties of crops, and progressive farmers incur expenditures for irrigation. The yardstick for a modernized farmer's expenditure is selected at Rs 25.00 per acre. The basis for this figure is the same as indicated in the discussion on fertilizer expenditure.

## Area in Peas

The yield potential of peas is very low compared with wheat. Thus percentage allocation of area to peas is taken to be an inverse measure of modernization.

## Area in Gram (Chick Peas)

Practically no fertilizer or manure is used in gram cultivation. It is a hardy crop and thrives well, even without irrigation. Thus percentage allocation of area to gram is an inverse measure of modernization.

## Area in Gochani (Wheat plus Chick Peas)

The practice of mixed cropping such as cultivation of "gochani" is not uncommon on the farms in northern India. Although this practice is rationalized as a measure against climatic hazards (i.e., untimely rain, etc.), crop yields are very low. A farmer allocating larger acreages to gochani cannot be designated as a modernized farmer. Thus, percentage allocation of area under "gochani" is an inverse measure of modernization.

## Area in Paddy

Progressive farmers allocate a large proportion of their land holdings to the paddy crop. The percentage of total area allocated under paddy crop is a direct measure of modernization.

## Area in Maize

Maize has long been the beneficiary of research in plant breeding. As a result, there has been a considerable increase in its production potential. A farmer who allocates larger acreages to maize reflects his responsiveness to the increased maize yields. Thus percentage of total area allocated to maize is considered a direct measure of modernization.

## Area in Wheat

Wheat is a superior cereal whose yield even prior to the adoption of the Mexican varieties, was higher than that of inferior cereals such as bajra and jowar. Percentage of total area allocated to this crop is considered a direct measure of modernization.

## Percentage of Irrigated Area in High Yielding Varieties

Availability of adequate irrigation is one of the essential requirements for the high yielding varieties of wheat, maize and paddy crops. Thus the percentage of irrigated area in high yielding varieties of each crop is taken as a direct measure of modernization.

## Level of Modernization in Irrigation

The type of irrigation facilities available to a farmer is an important aspect of modernization in that the greater the assured irrigation arrangement, the greater the risk bearing capacity of the farmer. Irrigation arrangements on the farms of Muzaffarnagar District vary from a canal and rainfed situation to modern electric and diesel pumps. The type of irrigation development on various farms in the area can be classified as follows:

a) Canal as source of irrigation,

b) Masonry wells as the source of irrigation,

c) Masonry well with a Persian wheel, and

d) Electric or diesel pump.

Sufficiency in terms of uniformity, speed and timeliness of irrigation varies, or rather, increases, as one moves from situation a to d. In order to construct a variable capable of describing the variations, a system of assigning weights was adopted. Therefore a weight of 1, 2, 3, and 4 was assigned to a, b, c, and d types of irrigation, respectively.

## Level of Modernization in Mechanization

Modernization in mechanization of agriculture is a relative term. The extent of mechanization is related to the size of a farmer's land holding. In North American agriculture, practically all farm operations are done with the help of machines. Modernization in mechanization in the present study refers to use of intermediate technology.

A cursory examination of various implements used by the farmers in the Muzaffarnagar District suggests that while some farmers own modern implements such as harrows and cultivators (which are mainly bullock drawn), the rest depend largely on desi ploughs. In order to incorporate this kind of variation in the use of farm implements, weights were assigned to various levels of technology. The pattern of ownership of implements was in the following order.

a) Wooden (desi) plough,

b) Chaff cutter,
c) Mould board plough,
d) Ridge maker,
e) Cultivator (bullock drawn), and
f) Harrow (bullock drawn)

The relative scales assigned to each type of technology are 1, 2, 3, 4, 5, and 6 for a, b, c, d, e and f, respectively. These weights represent the type of mechanical technology on the farms under study. For instance, if a farmer owned a mould board plough and a chaff cutter, the weight assigned to him was 3. Similarly, if a farmer owned a cultivator in addition to a mould board plough, the weight assigned was 5 and so on.

## Consolidation of the Land Holdings

The fragmented state of land holdings affects the allocative efficiency of farmers in a number of ways and prevents farmers from investing in items such as electric pumps and improved implements. For instance, if a farmer owns three acres of land and this land is distributed in four parts with a considerable distance between each part, he may not make an investment in an electric pump, even though he may want to do so. A number of problems associated with property rights emerge if he wants to pass irrigation water from one fragment to another through the intervening plots of other farmers. It is not possible to attain proper tilth on small plots because a part of the plot remains untilled due to back furrow. Cases of litigation occur when a farmer takes his cart to his various fragments, damaging the crops in intervening fields. The extent of consolidation of land holdings is regarded as a direct measure of modernization.

An index of consolidation was constructed in a manner which described the likely effects of consolidation (or fragmentation) on the efficiency of farmers. If a farmer's total land holding was located at one place, the weight given to him was 10. Similarly if a farmer's land holding consisted of two fragments, the weight given to him was 5 and so on.

Expenditure on Storage Arrangements

In spite of the fact that the excess of farm output over the annual consumption requirement of a farmer's family tends to be small in India, lack of storage is a serious problem on farms. A considerable quantity of grain is lost when it is stored in dwelling houses. Per acre expenditure for storage on a farm was considered a direct measure of modernization.

### Grouping the Farms According to Modernization Characteristics

In order to study the effects of modernization, information was needed about both modernized and non-modernized farms. There were 150 farms in the sample. Each farm was identified as being modernized or non-modernized. This section discusses the manner in which the classification of farms was performed.

Classification was done on the basis of modernization characteristics. There was a question of selecting an appropriate statistical method for this purpose. Classification would have been simple had there been only one feature on the basis of which a farm could be identified. For example, if per hectare expenditure on fertilizer was the only relevant characteristic for determining the extent of modernization, the use of one of the measures of central tendency would be sufficient for the purpose of classification. The farms could be grouped into the categories of modernized and non-modernized on the basis of succorance of observed values of expenditure to the mean value. In the present study complications arose because the units of measurement of various modernization characteristics varied. For example, while some of the criteria were expressed in terms of percentages, the others were expressed in rupees per hectare. The characteristics of modernization in mechanization or irrigation improvement were expressed in terms of scores.

The problems of variation in the nature of data and units of measurements can be overcome by discriminant analysis.[1] This approach involves a simple scoring system in which each individual is assigned a score. The score for an individual case is determined by adding up products of various independent variables and their discrimiant coeffiients.

While performing discriminant analysis, it is assumed that each individual's discriminant score, Zi, is the linear function of the independent variables. The discriminant score can be represented algebraically as follows:

$$Zi = b_0 + b_1X_{1i} + \ldots\ldots + bjXji \quad .$$

where:

Zi = The discriminant score of farm i,

bj = The discriminant coefficient for the j$^{th}$ variable, and

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[1] For statistical inference in classificatory problems, the use of discriminant analysis is very common. For an elementary exposition see: Donald G. Morrison, "Discriminant Analysis," in Robert Ferber, Handbook on Marketing Research (New York: McGraw-Hill, 1974), pp. 2-442-457; for a rigorous treatment on this subject, see: C.R. Rao, Advanced Statistical Methods in Biometric Research (New York: John Wiley and Sons, Inc., 1952), pp. 273-315, and John P. Van de Geer, Introduction to Multivariate Analysis for the Social Sciences (San Francisco: W.H. Freeman and Co., 1971), 243-272.

Xji = The $i^{th}$ farm's value of the $j^{th}$ independent variable.

Having obtained the score for a farm, it is compared with the critical value of the discriminant score.

The classification procedure is:

If $Zi > Zcrit.$, classify farm i as belonging to group I,

If $Zi < Zcrit.$, classifiy farm i as belonging to group II,

where:

Zcrit is the classification boundary. That is:

$$Zcrit = b_0 + b_1X_{1i} + b_2X_{2i} + \ldots\ldots + bjXji$$

## The Discriminant Model

An *a priori* assumption was made in which each of the modernization characteristics possessed a reasonable degree of discriminating power and consequently each of them was included in the model. The discriminant model for constructing the scores for different farms was developed in the following manner.

$$Zi = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 + b_6X_6 + b_7X_7 + b_8X_8 + b_9X_9 + b_{10}X_{10} + b_{11}X_{11} + b_{12}X_{12} + b_{13}X_{13} + b_{14}X_{14} + b_{15}X_{15} + b_{16}X_{16} \cdots$$

where:

$b_0$ = Constant term,

$b_1 \ldots\ldots j$ = Discriminant coefficients,

$X_1$ = Per hectare expenditure on fertilizer

$X_2$ = Per hectare expenditure on irrigation,

$X_3$ = Percentage area under gochani,

$X_4$ = Percentage area under peas,

$X_5$ = Percentate area under gram,

$X_6$ = Modernization in irrigation,

$X_7$ = Modernization in mechanization,

$X_8$ = Percentage area under wheat,

$X_9$ = Percentage area under paddy,

$X_{10}$ = Percentage area under maize,

$X_{11}$ = Percentage area under paddy and maize,

$X_{12}$ = Percentage irrigated area under paddy,;

$X_{13}$ = Percentage irrigated area under maize,

$X_{14}$ = Percentage irrigated area under wheat,

$X_{15}$ = Extent of consolidation of the land holiding, and

$X_{16}$ = Per hectare expenditure on storage arrangement.

## Results

The results are presented in Table 7.2.[1]

The results indicated that out of 150 farms, 91 were relatively modernized farmers and 59 were relatively non-modernized or backward farmers.

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[1] Information was required about a certain number of modernized and non-modernized farms for estimating the discriminant function. For this purpose, two sets of farms were selected; one representing modernized farms and the other representing non-modernized. Each set consisted of 11 such farms. This discriminant function is presented in Appendix C.

## TABLE 7.2

## CLASSIFICATION OF THE FARMS ON THE BASIS OF THE DISCRIMINANT MODEL

| Actual Group | Number of Cases | Predicted Group Membership<br>Group I | <br>Group II |
|---|---|---|---|
| Group I | 11 | 11 | 0 |
| Group II | 11 | 0 | 11 |
| Ungrouped Cases | 128 | 80 | 48 |
| TOTAL | 150 | 91 | 59 |

Note: In the above, Group I denotes relatively modernized farms, Group II denotes relatively non-modernized farms.

### Determining the Efficiency of Energy Resources in Wheat Cultivation on Both Types of Farms

In order to analyze the efficiency of energy resources in the cultivation of wheat crop, data pertaining to energy output and energy input were needed. For this purpose, various inputs that were used in production of wheat were taken into account. For establishing energy input-output relationships in wheat production, the wheat output and various inputs were expressed in terms of energy.

### Data and Construction of Variables

Data for the year 1966-67 were obtained from the Center for Farm Management Studies at Agra. The wheat data for various farms in the sample consisted of human labour, bullock power, seed, fertilizer and irrigation. There was variation in the units of measurement of the inputs-- for example, human labour and bullock power were measured in hours of work, fertilizer and irrigation were measured in rupees and wheat output was measured in kilograms. Therefore, various inputs required in wheat production needed to be measured in terms of energy units. The first task in performing the analysis was to convert all of the inputs into energy units (kilojoules).

Human Labour-- Data on use of human labour on each farm consisted of the hours of work performed by family members and hours of work performed by hired workers. For converting this work into kilojoules, the concept of "useful energy" was utilized whereby each hour of human effort was considered to be equivalent to 32 kilocalories or 134 kilojoules.

Wheat Seed-- A kilogram of wheat is equivalent to 3,300 kilocalories of energy[1] or 13.814 megajoules. Therefore, in determining the amount of energy contained in seed, the quantity of seed was multiplied by the factor of 13.8 megajoules.

Fertilizers-- In the survey conducted by the Center for Farm Management Studies at Agra, data on fertilizer use on various farms in the sample were collected in terms of rupees per hectare. During the period when the survey was conducted, the price of urea was Rs 100.00 per quintal (100 kg). Thus, each rupee would purchase about 0.46 kg of nitrogen. Expressed in terms of energy, each rupee spent on nitrogeous fertilizers was equivalent to 18.9 megajoules.[2] On this basis, the variable representing the energy contained in fertilizer was computed.

Bullock Power-- In the Center's survey the data regarding use of bullock power for wheat cultivation on each farm referred to hours of work performed by bullocks. The energy contained in an hour of work performed by a bullock is estimated at 1.745 megajoules.[1] Thus, to arrive at the total amount of energy expended on wheat cultivation on each sample farm, the total number of hours was multiplied by the factor 1.745.

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[1] See Pimental, et al., Workshop on Research Methodologies for Studies on Energy, Food and Environment: Phase I (Ithaca, New York: Cornell University Center for Environmental Quality Management, 1974), p. 28.

[2] See Ibid., pp. 1-20.

Irrigation-- The irrigation data were also collected in terms of expenditure of rupees per hectare. At the time when the survey was conducted, the water rates for tubewell irrigation were Rs 22.00 for each 1,000 cubic meters of water.[2] The task of pumping out 1,000 cubic meters of water required about 29.45 hours of work from a 5 horsepower motor. An expenditure of one rupee would purchase 1.339 hours of work by a 5 horsepower motor. Therefore, one rupee spent on irrigation was equivalent to 18 megajoules of energy. When computing the amount of energy in wheat production through tubewell irrigation, the amount of expenditure which was stated to have been incurred was multiplied by the factor 18.

## Data Analysis and Results

In order to analyze the effects of relative modernization, the use of important inputs and the amount of output per hectare in wheat cultivation were expressed in terms of an energy accounting basis and a monetary accounting basis for both modernized and non-modernized farms. The inputs under study were: human labour, bullock power, seed, fertilizer and irrigation. Two sets of analyses were performed: one for determining energy efficiency and the other for analyzing average returns per rupee of input expenditure in growing one hectare of wheat.

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[1] Various aspects of energy flows in regard to Indian cattle have been discussed in a classic study done by Stewart Odend'hal. For details see his article "Energetics of Indian Cattle in Their Environment," Human Ecology, Vol. 1, No. 1 (1972), pp. 3-22.

[2] See: T.V. Moorti, A Comparative Study of Well Irrigation in Aligarh District, India, Occasional Paper No. 29 (Ithaca, New York: Department of Agricultural Economics, Cornell University, 1970), p. 12.

In determining energy efficiency, the per hectare wheat output and the per hectare use of inputs were expressed in megajoules for each farm. The per hectare energy output was divided by the per hectare energy equivalent of a given input in estimating the energy productivity of that particular input. The energy output-input ratios for each of the five inputs for both categories of farms were calculated. In this manner, two sets of energy output-input ratios were obtained. Further, the per hectare energy output was divided by the sum total of per hectare use (in energy units) of all five inputs to estimate the overall energy efficiency for both types of farms. The mean values of each of the energy output-input ratios (across all farms of a given category) were computed (Table 7.3). The test of difference between the sample means was applied in order to examine the difference between the energy efficiency on modernized and non-modernized farms. The results presented in Talbe 7.3 suggest that the energy efficiency of factors such as human labour, bullock power, and seed is significantly higher on modernized farms than on non-modernized farms. The energy efficiency of fertilizer and irrigation is higher on the non-modernized farms than on the modernized farm. The difference in energy efficiency between the two types of farms can be attributed to the low level of fertilizer and irrigation application on the non-modernized farms. Despite such differences, the overall energy efficiency is higher on the modernized farms than on the non-modernized farms. The overall energy output-input ratio is 6.9 on the modernized farms whereas it is 6.4 on the

## TABLE 7.3

## ENERGY EFFICIENCY ON MODERNIZED AND NON-MODERNIZED FARMS

| | Group | Number of Farms | Average Energy Return Per Megajoule of Energy Input | Standard Deivation | t-Ratio |
|---|---|---|---|---|---|
| Human Labour | I | 91 | 267.9 | 91.8 | 5.41** |
| | II | 57 | 197.3 | 60.9 | |
| Bullock Power | I | 91 | 148.3 | 50.7 | 4.80** |
| | II | 57 | 108.9 | 44.6 | |
| Seed | I | 91 | 4,232.3 | 1,644.8 | 4.07** |
| | II | 57 | 3,216.5 | 1,153.3 | |
| Fertilizers | I | 91 | 9,886.5 | 8,291.1 | -4.40** |
| | II | 57 | 90,130.3 | 173,819.7 | |
| Irrigation | I | 91 | 54.2 | 40.8 | -5.94** |
| | II | 57 | 485.1 | 691.5 | |
| Overall Energy Output-Input Ratio | I | 91 | 6.9 | 2.1 | 1.48* |
| | II | 57 | 6.4 | 2.2 | |

Note: * Represents significance at the 10 percent level of probability.

** Represents significance at the 5 percent level of probability.

Group I denotes relatively modernized farms and Group II denotes relatively non-modernized farms.

non-modernized farms.[1]

With respect to the economic aspects of relative modernization, the average returns per rupee of expenditure were calculated for each input used on both modernized and non-modernized farms. Total revenue from the per hectare wheat output was divided by the per hectare input expenditure to determine average return per rupee expenditure of a given input. Further, the ratios of total revenue to per hechare expenditure of all five inputs for both types of farms were calculated. Mean values of such ratios were computed and subjected to the test of differences between sample means.

The results presented in Table 7.4 suggest that average returns per rupee of expenditure on human labour, bullock power and seed are higher on the modernized farms than on the non-modernized farms. Average returns per rupee expenditure on fertilizer and irrigation are higher on the non-modernized farms than on the modernized farms. However, on the whole, revenue per rupee of input use is higher on the modernized farms than on non-modernized farms. This difference, in fact, is statistically significant at the 5 percent level of probability. The results of both the energy and the economic accounting analyses suggest that the strategy of relative modernization may prove to be appropriate because it does not result in displacement of animate energy and it helps to increase the productivity

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[1] The overall energy output-input ratios on the two types of farms are considerably high. These results are in contradiction with the First Law of Thermodynamics. It is important to mention for the purpose of clarity that the list of inputs used in the present study consisted of only five inputs. A number of factors that go into crop production such as solar energy, chemical energy present in the soil, etc. were not included in the analysis. The high ratios of overall energy output to energy input are probably due to such omissions.

## TABLE 7.4

## COMPARISON OF AVERAGE RETURNS PER RUPEE OF INPUT EXPENDITURE IN GROWING ONE HECTARE OF WHEAT ON MODERNIZED AND NON-MODERNIZED FARMS

| | Group | Number of Farms | Average Return Per Rupee of Input Expenditure | Standard Deviation | t-Ratio |
|---|---|---|---|---|---|
| Human Labour | I | 91 | 3.95 | 1.35 | 5.14** |
| | II | 57 | 2.91 | 0.89 | |
| Bullock Power | I | 91 | 15.08 | 5.15 | 4.80** |
| | II | 57 | 11.08 | 4.54 | |
| Seed | I | 91 | 12.81 | 4.98 | 4.07** |
| | II | 57 | 9.73 | 3.49 | |
| Fertilizer | I | 91 | 28.78 | 24.13 | -4.40** |
| | II | 57 | 262.36 | 505.97 | |
| Irrigation | I | 91 | 53.64 | 40.45 | -5.94** |
| | II | 57 | 480.38 | 684.78 | |
| Revenue per Rupee | I | 91 | 2.24 | 0.68 | 5.16** |
| | II | 57 | 1.74 | 0.48 | |

Note: ** Represents signifiance at the 5 percent level of probability.

of resources.[1]

The Muzaffarnagar data on wheat cultivation show that a fair degree of modernization can occur in Indian agriculture provided that farmers adopt an improved package of practices. The overall productivity of resource inputs was higher on relatively modernized but not tractor using, farms of the area in 1966-67. One suspects that the productivity differential between relatively modernized and non-modernized farms has widened as the adoption of new wheat varieties has spread.

Modernization can be achieved through small and indigenously developed equipment which is easily operated and repaired and which is operated by human labour and bullock power. A relevant strategy of modernizing Indian agriculture should aim at popularizing "intermediate technology".

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[1] Use of animate energy resources such as human labour and bullock power in growing one hectare of wheat on the modernized farms was approximately the same. Mean levels of per hectare use of human labour, bullock power, seed, fertilizer and irrigation for modernized and non-modernized farms were subjected to the test of difference between the sample means. The test confirmed the above propositon. See: Appendix E, for details.

# CHAPTER VIII

## SUMMARY, CONCLUSIONS AND POLICY IMPLICATIONS

The question of modernizing Indian agriculture has been a longstanding problem. Past efforts made by the Government of India in this regard were oriented towards increasing food production. After experimenting with a number of ideas, the government came to recognize the Green Revolution as the most effective strategy for modernizing Indian agriculture.

The basic notion that the transformation of traditional agriculture is closely tied to the increased application of science and technology in the agricultural sector cannot be questioned. However, certain features have emerged during the Green Revolution which have serious implications for the Indian economy and for agricultural modernization. The Green Revolution has resulted in increased dependence of the agricultural sector on commercial energy resources. Certain features that have emerged along with the Green Revolution are related to the problem of unemployment of human labour and bullock power. This study has examined various aspects of agricultural modernization, particularly energy use, in the light of the Green Revolution experience.

### Summary and Conclusions

The fundamental thesis of this study was that agricultural modernization depends upon the use of inanimate energy resources. Mere emulation of strategies which have been successful elsewhere may not serve the objective of achieving modernization in Indian agriculture. Since animate energy resources are abundant in rural areas and the opportunities to utilize them elsewhere in the country are limited, it was suggested that increased use of inanimate energy resources should not result in displacement of animate energy resources.

The inquiry began with a survey of changes pertaining to the agricultural use of commercial energy resources since the early years of India's independence. The use of energy intensive items such as fertilizers, tractors and irrigation pumps has increased significantly in Indian agriculture. The increase in utilization of these items was pronounced in the years following the start of the Green Revolution. Since the requirement for food grains in India is likely to increase, the government is likely to continue to emphasize adoption of high yielding cereal varieties of crops. On the basis of this assumption it was concluded that the dependence of the agricultural sector on commercial energy resources will further increase in future years.

The increase in consumption of commercial energy has many implications for the Indian economy. Of immediate interest was the question of availability of commercial energy resources. Upon examination of estimates of reserves, production and consumption, it was concluded that except for coal, the availability of commercial energy resources is extremely limited in India.

There has been a major change in the pattern of ownership of commercial energy resources in the post-independence period. During the last two decades, the public sector's share in the ownership of commercial energy resources has increased. Success in procuring energy supplies depends upon the ability of government to increase domestic production and to facilitate the distribution of resources in various parts of the country. India is very poor in petroleum reserves. Since the onset of the energy crisis in recent years, the Government of India has imported about 34 percent of its petroleum requirements. Petroleum has become an important ingredient in

Indian agriculture. It is not only the source of power for irrigation pumps and tractors, it is also the source of feedstock (i.e., naptha) in fertilizer production. The availability of petroleum is an important factor in the development of Indian agriculture, and the prospects of assured availability depend upon the export earnings of the Indian economy and India's relations with oil exporting countries.

The increasing dependence of the agricultural sector on commercial energy resources has implications for the utilization of animate energy. For example, the use of tractors may result in the displacement of human labour and bullock power in cultivation of wheat, maize and paddy crops. The prospects of employment for persons displaced due to mechanization are extremely limited in the Indian economy. Despite such implications, the increase in the number of tractors is regarded by some observers as an important aspect of agricultural modernization in India. Attention, therefore, was focussed on the meaning, scope and relevance of the term "modernization". The term"modernization"should relate to the question of increased productivity as well as to use of animate energy resources in the context of Indian agriculture. The economic aspects of modernization should be viewed from the standpoint of causes and effects. The cause of a transition leading to modernization is reflected in increased use of animate energy resources whereas the effects are reflected in increased productivity of animate energy resources.

The question of modernizing Indian agriculture may be examined or understood from certain standpoints. In the first place, an increase in the use of inanimate energy resources is required in agricultural production. Secondly, the increase in use of inanimate energy resources should not result in the net displacement of human labour. Thirdly, the country is not well endowed with inanimate energy resources. In consideration of the scarcity of inanimate energy resources, priorities for allocation of available resources should be carefully determined by the government. To this end an inquiry into the significance of energy intensive inputs (namely, fertilizers, irrigation and tractor use) in cereal production in India was undertaken. A regression model for describing the production relations in cereal crops was developed and analyzed. The results showed that while the coefficients associated with irrigation and, to some extent, fertilizers, were significantly different from zero, the coefficient for tractor use was not significant. Therefore, the use of fertilizers and irrigation should be given high priority in Indian agriculture. Further studies are needed to examine the role of tractors in agricultural production in India.

Although Indian agriculture remains overwhelmingly dependent upon bullocks for draft power, the increasing use of tractors in some sectors of Indian agriculture is an emerging policy concern. Models were developed to analyze the effects of tractor use on the output of cereal crops and the employment of animate energy resources. It was observed that increased use of tractors in the cultivation of wheat and maize crops did not result in increased output within the cropping season. In the cultivation of paddy, however, output increased with increased tractor use.

The implications of tractor use were also examined in terms of the direct in-season effects on the use of animate energy in the cultivation of wheat, maize and paddy crops. A model based on the concept of "useful energy" obtainable from tractors, agricultural workers and bullocks was developed. Data collected from G.B. Pant University of Technology and Agriculture were utilized in the analysis. In describing energy relations, the "plough unit" was developed, each unit being eight hours of work performed by one worker and two bullocks.

Neglecting the impacts of tractor use on indirect employment and on multiple cropping, tractor use resulted in the displacement of human labour and bullock power. The extent of displacement of human labour and bullock power due to tractor use varies from one crop to another. The displacement potential of a tractor is high in the case of wheat and paddy crops. One hour of tractor use results in displacement of 1.7 plough units in the cultivation of wheat and 2 units in the case of paddy crop. For maize, the displacement potential is 1.2 plough units. The implications of tractor use were discussed in the light of these results. It was calculated that a 35 horsepower tractor, operated in a wheat growing region, would displace about 2,040 plough unit days a year. The extent of displacement in maize and paddy growing regions was also calculated in terms of plough units.

The question of achieving a state of relative modernization in Indian agriculture was also examined. Analysis was carried out to determine whether or not an increase in productivity of energy resources could be achieved through a modest degree of improvement in inputs and equipment. In 1966-67, a sample consisting of 150 farms in the Muzaffarnagar district was analyzed. The characteristics of agricultural modernization were enumerated. On the basis of these characteristics, each farm was identified as either modernized or non-modernized. A discriminant analysis was used to perform this classification. In the sample, 91 farms were identified as relatively modernized and 59 as relatively non-modernized. Subsequently, energy use on modernized and non-modernized farms in wheat cultivation was analyzed. Using an energy accounting procedure, the efficiency of use of inputs such as human labour, bullock power, seed, fertilizer and irrigation was calculated for both types of farms. The overall energy return per megajoule of energy expenditure in wheat cultivation was also calculated for each type of farm. That is, the mean values of overall energy efficiency and the energy efficiency of each input obtaining on both types of farms were calculated. Each of the mean values of the ratios relating to relatively non-modernized farms was compared with those for the relatively modernized farms. In a similar manner the average return per rupee of expenditure with respect to each input and the overall return per rupee of aggregate input expenditure were calculated. It was concluded that the efficiency of animate energy was higher on the relatively modernized farms than on the non-modernized farms. Also, the overall energy return per megajoule was higher on the modernized farms. The results pertaining to the economic analysis also showed that the return per rupee of input expenditure was higher on the modernized farms as well. The productivity of resources can be increased without a significant increase in the use of animate energy in Indian agriculture through a strategy centered upon relative modernization.

Rather than emulating the agricultural techniques of advanced countries, the Government of India should emphasize the case of "intermediate technology". This approach will not only result in increased production but may also ensure utilization of the animate energy resources.

## Implications of the Study

The study has implications for four areas: (1) the government's energy policy for the agricultural sector, (2) nature and scope of modernization of Indian agriculture, (3) the methods of research pertaining to energy use in agriculture and agricultural modernization, and (4) the question of the changing structure of prices of agricultural commodities.

India stands at a critical juncture in that the assured availability of commercial energy resources, especially crude oil, is extremely important for the development of the Indian economy and these resources are procured largely through imports. While part of the energy problem is due to the fact that the country is not adequately endowed with oil reserves, a large part of the problem is attributable to lack of systematic planning by the government. The phenomenal growth in the number of tractors in the agriculture sector is a case in point. In the past, rather than imposing restrictions on the purchase of tractors by farmers, the government subsidized their purchase.

The results of this study showed that increased use of tractors does not result in increased output of maize and wheat crops within given cropping seasons. The paddy crop does, however, respond to tractor use in tillage operations. Surprisingly, growth in the number of tractors has occurred mainly in the wheat and maize growing areas such as Punjab, Haryana, and Uttar Pradesh states. The paddy growing regions of India have not witnessed much increase in the number of tractors. The study lends support to the view that selective mechanization of rice tillage operations could be essential to the growth of rice output.

A potentially important but greatly underresearched issue in India is the question of selective mechanization involving power tillers of perhaps 5 to 10 horsepower in rice production. Such tillers would appear to have played an instrumental role in the expansion of rice production in Taiwan and the Peoples' Republic of China.

As for the nature and scope of modernization of Indian agriculture, these aspects should be assessed in a manner commensurate with the availability of resources in the economy. The manner in which the concept of modernization has been used by "planners" seems to suggest that it has been more or less a step towards emulating the agricultural practices of advanced countries. While this possibility could occur on large farms, the prospects of its dissemination throughout the agricultural sector are extremely limited in that the majority of land holdings are small. Because of the unequal distribution of land holdings, government programmes for increasing the number of tractors and other heavy equipment will result in a bimodal system of agricultural production in which farmers with relatively large land holdings will be entirely different from the rest of the farming community in terms of asset structure, labour use and methods of cultivation.

The main implication of this study was that aspects such as the impending scarcity of commercial energy resources, their contribution to total agricultural production and the utilization of human labour and bullock power should be taken into account while launching modernization programmes. The question of utilization of animate energy in the agricultural sector is particularly important in that the prospects of their employment elsewhere in the economy do not seem to exist.

With respect to methods of research, two areas were explored: first, the suitable method for determining the state of modernization in a given community and second, the methods for analyzing energy efficiency in traditional agriculture.

Concerning the first area, although the conceptualization of modernization of traditional agriculture has been discussed by a number of authors, it warrants reconsideration. These authors have focussed their attention on one or two aspects of traditional agriculture such as low productivity, economic rationality and marketable surplus. In doing so, the approaches have turned out to be monistic. In this study, modernization of a community or an industry has been taken to mean a composite index which accounts for various transitions resulting in several continua. For this purpose, the use of discriminant analysis was found to be suitable. The use of this technique may prove to be of immense help to planners who are interested in discerning who is a progressive or modernized farmer or who deserves more attention from the government and other institutions in a given community of farmers.

The analysis of energy use in traditional agriculture is a relatively new field. It is hoped that concepts such as "useful energy", "plough unit" and "displacement elasticity" will prove to be of considerable help to those who may be pursuing this area of study.

In recent years the prices of pulse commodities have been increasing at a faster rate than those of cereals. The prospect that pulse prices will increase relative to cereal prices, at least in the short run, has certain implications for the adoption of high yielding varieties and the use of modern inputs. Pulse crops compete with cereal crops-- particularly with dryland cereals and, to some degree, with irrigated cereals in Northern India. In response to relative price changes, farmers may start allocating larger acreages to pulse crops. As a result, the adoption of modern varieties may be somewhat retarded and the demand for fertilizers and irrigation may be dampened. A naive predictive model was developed to examine the question of relative changes in pulse and cereal prices in future years

(Appendix D). The results indicated that pulse prices are more sensitive to the per capita availability of pulses than are cereal prices to the per capita availability of cereals. Since the per capita availability of pulses has been declining in the Indian economy, it was concluded, that their prices are apt to increase in coming years relative to cereal prices. It was also indicated that this possibility will adversely affect the adoption of high yielding varieties of cereal crops.

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# APPENDIX A

# APPENDIX A

## A-1

## DEFINITIONS OF ADMINISTRATIVE UNITS IN INDIA

District: A unit of administration, responsible for maintaining law and order, collecting revenues from business and farming communities and for development of plans and implementation thereof in the area.

Tehsil: A unit of administration in a district, responsible for collecting revenues, distribution of subsidies to the farmers and effective settlement of disputes litigation arising out of land sales and purchases.

Development Block: With a view to developing agriculture, the Government of India launched a nationwide Community Development Programme. For this purpose a unit of development consisting of 10-30 villages was designated as development block. It consists of experts on various facets of rural communities who are accountable to the District Planning Officer.

## A-2

## CONVERSION FACTORS

In India, the estimates of consumption and requirement of energy from different sources are generally presented in terms of million tons of coal replacement. This is done in order to provide a clear picture of relative shares of various forms of resources in the overall energy matrix of the Indian economy. In this regard the conversion factors adopted by the Energy Survey of India Committee were as follows:[1]

1 ton of hard coke = 1.3 tons of coal

1 ton of soft coke = 1.5 tons of coal.

1 ton of dried dung replaces 0.27 ton of soft coke = 0.40 tons of coal.

1 ton of firewood replaces 0.63 tons of soft coke = 0.95 tons of coal.

1 ton of waste products (crop residues) replaces 0.63 ton of soft coke = 0.95 tons of coal.

1 ton of charcoal = 1 ton of coal.

1 ton of motor spirit = 7.5 tons of coal

1 ton of kerosene and LPG = 8.3 tons of coal.

1 ton of diesel oil = 9 tons of coal.

1 ton of heavy stock = 2 tons of coal.

1000 kwh of electricity = 1 ton of coal.

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[1] For details see: Kirit S. Parikh, Second India Studies: Energy (Delhi: The McMillan Company of India Otd., 1976) p. 34, and P.D. Henderson, India: the Energy Sector (Washington D.C., International Bank for Reconstruction and Development: 1975), pp. 177-181.

# APPENDIX B

## Table B-1

## CONSUMPTION OF FERTILIZERS IN INDIA
(1952/53-1973/74)
(Thousand Tonnes)

| Year | Nitrogen (N) | Phosphate ($P_2O_5$) | Potash ($K_2O$) |
|---|---|---|---|
| 1952-53 | 57.8 | 4.6 | 3.3 |
| 1953-54 | 89.3 | 8.3 | 7.5 |
| 1954-55 | 94.8 | 15.0 | 11.1 |
| 1955-56 | 107.5 | 13.0 | 10.3 |
| 1956-57 | 123.1 | 15.9 | 14.8 |
| 1957-58 | 149.0 | 21.9 | 12.8 |
| 1958-59 | 172.0 | 29.5 | 22.4 |
| 1959-60 | 229.3 | 53.9 | 21.3 |
| 1960-61 | 211.7 | 53.1 | 29.0 |
| 1961-62 | 291.5 | 63.9 | 28.0 |
| 1962-63 | 360.0 | 81.4 | 36.4 |
| 1963-64 | 407.0 | 116.7 | 50.6 |
| 1964-65 | 434.5 | 147.7 | 70.4 |
| 1965-66 | 547.4 | 132.2 | 77.7 |
| 1966-67 | 838.7 | 248.6 | 115.7 |
| 1967-68 | 799.5 | 236.5 | 129.8 |
| 1968-69 | 1,131.3 | 389.2 | 154.2 |
| 1969-70 | 1,360.3 | 419.8 | 209.4 |
| 1970-71 | 1,487.1 | 462.0 | 228.2 |
| 1971-72 | 1,755.4 | 564.0 | 304.0 |
| 1972-73 | 1,778.9 | 587.4 | 332.5 |
| 1973-74 | 1,835.0 | 634.0 | 314.0 |

Source: Adopted from Fertilizer Statistics 1973/74, New Delhi: Fertilizer Association of India, 1975), p. I-85.

Table B-2

## INDEX OF AGRICULTURAL PRODUCTION AND RELATIVE PRICES OF TRACTORS

| Year | Index of Agricultural Production | Relative Price |
|---|---|---|
| 1955-56 | 116.8 | 139.5 |
| 1956-57 | 124.3 | 117.5 |
| 1957-58 | 115.9 | 114.4 |
| 1958-59 | 133.5 | 107.8 |
| 1959-60 | 130.3 | 105.4 |
| 1960-61 | 142.2 | 99.2 |
| 1961-62 | 144.8 | 100.0 |
| 1962-63 | 139.6 | 108.5 |
| 1963-64 | 143.1 | 101.7 |
| 1964-65 | 159.4 | 85.9 |
| 1965-66 | 133.1 | 76.8 |
| 1966-67 | 131.6 | 86.3 |
| 1967-68 | 161.1 | 76.4 |
| 1968-69 | 159.5 | 80.3 |
| 1969-70 | 170.8 | 74.0 |
| 1970-71 | 182.2 | 71.7 |
| 1971-72 | 191.3 | 89.8 |

Source: National Council of Applied Economic Research. Demand For Tractors (New Delhi: National Council of Applied Economic Research: 1974), p. 9.

## Table B-3

## TRACTOR STOCK IN USE IN AGRICULTURE FOR 1955/56-1971/72

| Year | Production | Imports | Stock |
|---|---|---|---|
| | | (Number of Tractors) | |
| 1955-56 | | | 20,980 |
| 1956-57 | | 4,792 | 23,711 |
| 1957-58 | | 3,733 | 25,839 |
| 1958-59 | | 2,652 | 27,351 |
| 1959-60 | | 3,843 | 29,541 |
| 1960-61 | | 2,586 | 31,015 |
| 1961-62 | 880 | 2,997 | 34,349 |
| 1962-63 | 1,414 | 2,616 | 37.815 |
| 1963-64 | 1,983 | 2,349 | 41,540 |
| 1964-65 | 4,323 | 2,323 | 47.255 |
| 1965-66 | 5,796 | 1,939 | 53,966 |
| 1966-67 | 8,816 | 2,591 | 63,776 |
| 1967-68 | 11,394 | 4,038 | 77,047 |
| 1968-69 | 15,437 | 12,397 | 100,984 |
| 1969-70 | 17,101 | 12,701 | 126,614 |
| 1970-71 | 19,535 | 16,679 | 157,758 |
| 1971-72 | 16,535 | 16,000 | 185,738 |

Source: National Council of Applied Economic Research, *Demand for Tractors* (New Delhi: National Council of Applied Economic Research, 1974), pp. 6-7.

## Table B-4

## DATA ON AGRICULTURAL LABOUR FORCE AND CEREAL FOOD GRAINS IN INDIA

| Year | Labour in Agriculture (Million) | Area (Thousand Hectares) | Production (Million Tonnes) |
|---|---|---|---|
| 1956 | 67.93 | 87,346 | 57.33 |
| 1957 | 68.92 | 87,824 | 57.25 |
| 1958 | 69.97 | 86,225 | 54.75 |
| 1959 | 71.02 | 88,885 | 63.99 |
| 1960 | 72.98 | 90,990 | 64.87 |
| 1961 | 73.97 | 92,018 | 69.31 |
| 1962 | 77.98 | 92,989 | 70.95 |
| 1963 | 82.21 | 93,579 | 68.62 |
| 1964 | 86.66 | 93,235 | 70.59 |
| 1965 | 91.35 | 93,740 | 76.56 |
| 1966 | 96.31 | 91,094 | 62.23 |
| 1967 | 101.50 | 93,181 | 65.88 |
| 1968 | 107.00 | 98,773 | 83.35 |
| 1969 | 112.80 | 99,166 | 83.59 |
| 1970 | 119.00 | 101,547 | 96.60 |
| 1971 | 125.67 | 101,782 | 94.10 |

Source: Data on production of and area in cereal crops were obtained from V.G. Pande, Data on Indian Economy - 1951 to 1969 (New Delhi: The Ford Foundation, 1970), Tables 3.01 to 3.10, and from various issues of Agricultural Situation in India (New Delhi: Directorate of Economics and Statistics). Data on agricultural labour force for the years 1956 to 1968 were obtained from the various issues Eastern Economist since 1969. The labour force in agriculture for the years, 1969 to 1971, was estimated on the basis of trends in overall labour force growth (i.e., 5.4 percent) in the country.

## Table B-5

## AREA, YIELD AND PRODUCTION OF IMPORTANT CEREAL FOOD GRAINS IN INDIA (1961-1974)

| | Wheat | | | Paddy | | | Maize | | |
|---|---|---|---|---|---|---|---|---|---|
| Year | Area (000'ha) | Yield (kg/ha) | Production (000' ton) | Area (000'ha) | Yield (kg/ha) | Production (000' tons) | Area (000'ha) | Yield (kg/ha) | Production (000' tons) |
| 1961 | 12,927 | 851 | 10,997 | 34,694 | 1,542 | 53,494 | 4,507 | 957 | 4,312 |
| 1962 | 13,570 | 890 | 12,072 | 35,695 | 1,396 | 49,826 | 4,643 | 992 | 4,607 |
| 1963 | 13,590 | 793 | 10,776 | 35,809 | 1,550 | 55,497 | 4,582 | 995 | 4,561 |
| 1964 | 13,499 | 730 | 9,853 | 36,462 | 1,617 | 58,962 | 4,618 | 1,010 | 4,664 |
| 1965 | 13,422 | 913 | 12,257 | 35,273 | 1,304 | 45,983 | 4,799 | 1,005 | 4,823 |
| 1966 | 12,656 | 824 | 10,424 | 35,251 | 1,295 | 45,657 | 5,074 | 964 | 4,894 |
| 1967 | 12,838 | 887 | 11,393 | 36,437 | 1,548 | 56,418 | 5,583 | 1,123 | 6,269 |
| 1968 | 14,998 | 1,103 | 16,540 | 36,966 | 1,613 | 59,642 | 5,716 | 997 | 5,701 |
| 1969 | 15,958 | 1,169 | 18,652 | 37,680 | 1,609 | 60,645 | 5,862 | 968 | 5,674 |
| 1970 | 16,626 | 1,209 | 20,093 | 37,592 | 1,685 | 63,338 | 5,852 | 1,279 | 7,486 |
| 1971 | 18,241 | 1,307 | 23,833 | 37,334 | 1,717 | 64,102 | 5,637 | 892 | 5,026 |
| 1972 | 19,163 | 1,382 | 26,477 | 36,500 | 1,616 | 59,000 | 5,200 | 865 | 4,500 |
| 1973 | 19,466 | 1,271 | 24,735 | 38,011 | 1,726 | 65,613 | 6,021 | 937 | 5,643 |
| 1974 | 19,057 | 1,158 | 22,073 | 37,500 | 1,640 | 61,500 | 5,800 | 914 | 5,300 |

Source: Adopted from Production Yearbook. (Rome: Food and Agriculture Organization of the United Nations, 1972 and 1974), Vol. 26 and 28. Tables 13, 14 and 16.

## Table B-6

## AREA YIELD AND PRODUCTION OF IMPORTANT PULSE CROPS IN INDIA

| | Peas Dry | | | Beans Dry | | | Lentils | | | Pigeon Peas | | | Chick Peas | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | Area (000'ha) | Yield kg/ ha | Pro- 'tion (000'ton) | Area (000' ha) | Yield kg/ ha | Pro- 'tion (000'ton) | Area (000' ha) | Yield kg/ ha | Pro'- tion (000'ton) | Area (000' ha) | Yield kg/ ha | Pro'- tion (000'ton) | Area (000' ha) | Yield kg/ ha | Pro'- tion (000'ton) |
| 1962 | 1,258 | 817 | 1,103 | 6,726 | 268 | 1,805 | 771 | 442 | 340 | 2,447 | 559 | 1,367 | 9,566 | 605 | 5,785 |
| 1963 | 1,325 | 774 | 1,026 | 7,040 | 259 | 1,826 | 767 | 456 | 350 | 2,452 | 645 | 1,582 | 9,193 | 583 | 5,362 |
| 1964 | 1,300 | 516 | 671 | 7,332 | 281 | 2,059 | 785 | 368 | 289 | 2,517 | 548 | 1,380 | 9,354 | 481 | 4,502 |
| 1965 | 1,122 | 825 | 926 | 7,088 | 240 | 1,702 | 840 | 476 | 400 | 2,578 | 733 | 1,890 | 8,870 | 651 | 5,777 |
| 1966 | 1,109 | 727 | 807 | 7,247 | 233 | 1,689 | 843 | 437 | 369 | 2,556 | 678 | 1,733 | 8,015 | 527 | 4,224 |
| 1967 | 1,096 | 603 | 660 | 7,548 | 266 | 2,007 | 829 | 347 | 288 | 2,521 | 448 | 1,130 | 8,003 | 453 | 3,622 |
| 1968 | 1,029 | 923 | 950 | 7,407 | 252 | 1,865 | 752 | 510 | 384 | 2,665 | 653 | 1,741 | 8,257 | 723 | 5,972 |
| 1969 | 1,040 | 921 | 958 | 7,461 | 270 | 2,014 | 777 | 515 | 400 | 2,529 | 718 | 1,861 | 7,106 | 607 | 4,310 |
| 1970 | 989 | 781 | 772 | 7,796 | 309 | 2,409 | 763 | 502 | 383 | 2,669 | 690 | 1,842 | 7,752 | 715 | 5,546 |
| 1971 | 917 | 845 | 775 | 7,521 | 270 | 2,033 | 744 | 499 | 371 | 2,656 | 709 | 1,883 | 7,839 | 663 | 5,199 |
| 1972 | 869 | 757 | 658 | 7,185 | 223 | 1,602 | 800 | 520 | 416 | 2,346 | 718 | 1,683 | 7,912 | 642 | 5,081 |
| 1973 | 819 | 605 | 495 | 7,400 | 243 | 1,800 | 807 | 452 | 365 | 2,330 | 750 | 1,748 | 6,940 | 644 | 4,469 |
| 1974 | 765 | 494 | 378 | 8,779 | 282 | 2,473 | 725 | 440 | 407 | 2,646 | 532 | 1,408 | 7,761 | 528 | 4,099 |
| 1975 | 800 | 688 | 550 | 8,000 | 313 | 2,500 | 925 | 526 | 500 | 2,540 | 716 | 1,818 | 7,150 | 567 | 4,055 |

Source: Adopted from Production Yearbook. (Rome: Food and Agriculture Organization of the United Nations. 1973 &1975) Vol. 27 and 29. Tables 32, 34, 35, 37 and 38. pp. 97-102.

## Table B-7

## NATIONAL INCOME AND OTHER DETERMINANTS OF ENERGY REQUIREMENTS, INDIA

| Year | Nation Revenue (1960-61 prices) Rs million | Income From Mining & Manufacturing (1960-61 prices) Rs million | Index of Industrial Production 1960=100 |
|---|---|---|---|
| 1954-55 | 105,480 | 13,930 | 66.2 |
| 1955-56 | 109,070 | 15,160 | 71.9 |
| 1956-57 | 115,080 | 16,150 | 77.8 |
| 1957-58 | 113,480 | 16,670 | 80.7 |
| 1958-59 | 122,400 | 17,280 | 82.0 |
| 1959-60 | 124,620 | 18,430 | 89.1 |
| 1960-61 | 132,920 | 20,000 | 100.0 |
| 1961-62 | 137,630 | 21,790 | 109.2 |
| 1962-63 | 140,450 | 23,490 | 119.7 |
| 1963-64 | 148,450 | 25,590 | 129.7 |
| 1965-65 | 159,170 | 27,300 | 140.9 |
| 1965-66 | 150,210 | 27,870 | 153.7 |
| 1966-67 | 152,430 | 27,960 | 153.2 |
| 1967-68 | 166,600 | 28,650 | 151.4 |
| 1968-69 | 170,570 | 29,830 | 161.1 |
| 1969-70 | 179,200 | 31,330 | 172.5 |
| 1970-71 | 187,550 | 30,950 | 180.8 |

Source: Adopted from Kirit S. Parikh, Second India Studies, Energy (Delhi: The McMillan Company of India Ltd., 1976), pp. 36.

## Table B-8

## CONSUMPTION OF ENERGY IN INDIA (MILLION TONS OF COAL REPLACEMENT) 1953/54-1970-71

| Year | Commercial Energy | | | | Noncommercial Energy | | | | Grand Total |
|---|---|---|---|---|---|---|---|---|---|
| | Coal | Oil | Electricity | Total | Firewood | Dung | Agricultural Waste | Total | |
| 1953-54 | 28.7 | 23.8 | 7.6 | 60.1 | 82.2 | 18.6 | 25.1 | 125.9 | 186.0 |
| 1954-55 | 28.5 | 25.8 | 8.4 | 62.7 | 83.3 | 19.1 | 25.6 | 128.0 | 190.7 |
| 1955-56 | 28.8 | 30.3 | 9.4 | 68.5 | 84.4 | 19.6 | 26.3 | 130.3 | 198.8 |
| 1956-57 | 30.7 | 31.2 | 10.2 | 72.1 | 85.6 | 20.1 | 27.0 | 132.7 | 204.8 |
| 1957-58 | 34.6 | 33.9 | 11.8 | 80.3 | 86.9 | 21.6 | 27.7 | 135.2 | 215.5 |
| 1958-59 | 36.1 | 36.1 | 13.2 | 85.4 | 88.3 | 21.1 | 28.4 | 137.8 | 223.2 |
| 1959-60 | 35.7 | 40.1 | 15.4 | 91.2 | 91.7 | 21.3 | 28.7 | 141.7 | 232.9 |
| 1960-61 | 40.4 | 43.9 | 16.9 | 101.2 | 96.0 | 22.5 | 29.5 | 148.0 | 249.2 |
| 1961-62 | 40.2 | 48.5 | 19.4 | 108.1 | 97.3 | 22.4 | 29.9 | 149.6 | 257.7 |
| 1962-63 | 49.1 | 54.5 | 22.6 | 126.2 | 98.4 | 22.7 | 30.3 | 151.4 | 277.6 |
| 1963-64 | 48.6 | 56.2 | 25.2 | 130.0 | 101.5 | 23.4 | 31.3 | 156.2 | 286.2 |
| 1964-65 | 48.2 | 60.4 | 27.8 | 136.4 | 102.8 | 23.7 | 31.6 | 158.1 | 294.5 |
| 1965-66 | 51.8 | 64.6 | 30.6 | 147.0 | 106.3 | 24.5 | 32.7 | 163.5 | 310.5 |
| 1966-67 | 52.3 | 69.1 | 33.2 | 154.5 | 108.5 | 25.0 | 33.4 | 166.9 | 321.4 |
| 1967-68 | 54.5 | 73.3 | 36.8 | 164.6 | 111.1 | 25.6 | 34.2 | 170.9 | 335.5 |
| 1968-69 | 53.0 | 82.3 | 41.5 | 176.8 | 112.6 | 26.0 | 34.6 | 173.2 | 350.0 |
| 1969-70 | 56.6 | 90.1 | 45.0 | 191.7 | 114.2 | 26.4 | 35.2 | 175.8 | 367.5 |
| 1970-71 | 51.4 | 97.2 | 48.7 | 197.3 | 116.6 | 26.9 | 35.9 | 179.4 | 376.7 |

Source; Kirit S. Parikh, Second India Studies: Energy (Delhi: The McMillan Company of India Ltd., 1976), p. 18.

## Table B-9

## CONSUMPTION OF ELECTRICITY IN IRRIGATION, INDIA
(Million Kilowatt-Hours)

| Year | Electrical Energy for Irrigation |
|---|---|
| 1950-51 | 160.9 |
| 1951-52 | 201.1 |
| 1952-53 | 220.7 |
| 1953-54 | 229.9 |
| 1954-55 | 240.3 |
| 1955-56 | 280.3 |
| 1956-57 | 320.6 |
| 1957-58 | 444.5 |
| 1958-59 | 667.7 |
| 1959-60 | 720.0 |
| 1960-61 | 805.4 |
| 1961-62 | 859.2 |
| 1962-63 | 917.2 |
| 1963-64 | 1,187.3 |
| 1964-65 | 1,386.3 |
| 1965-66 | 1,790.4 |
| 1966-67 | 1,976.5 |
| 1967-68 | 2,838.8 |
| 1968-69 | 3,296.0 |
| 1969-70 | 3,757.0 |
| 1970-71 | 4,508.0 |
| 1971-72 | 5,502.0 |

Source: Adopted from Quaterly Bulletin Reserve Bank of India. Various issues since 1952.

## Table B-10

## DATA ON MONEY SUPPLY AND PRICE INDEX OF CEREALS AND PULSES IN INDIA

| Year | Price Index of Cereals | Price Index of Pulses | Money Supply (Million rupees) |
|---|---|---|---|
| 1955 | 71.2 | 59.2 | 218,445 |
| 1956 | 90.8 | 76.9 | 231,212 |
| 1957 | 95.2 | 76.9 | 238,935 |
| 1958 | 100.7 | 98.9 | 249,950 |
| 1959 | 98.1 | 89.0 | 270,313 |
| 1960 | 96.2 | 87.6 | 290,172 |
| 1961 | 100.0 | 100.0 | 286,861 |
| 1962 | 102.9 | 116.8 | 304,582 |
| 1963 | 112.0 | 129.7 | 330,997 |
| 1964 | 135.2 | 192.3 | 375,212 |
| 1965 | 146.2 | 191.0 | 408,028 |
| 1966 | 173.7 | 224.6 | 452,939 |
| 1967 | 206.4 | 227.6 | 494,920 |
| 1968 | 195.3 | 222.7 | 535,004 |
| 1969 | 201.3 | 239.1 | 638,654 |
| 1970 | 199.5 | 240.0 | 713,997 |
| 1971 | 202.3 | 271.7 | 813,796 |

Source: Adopted from Reserve Bank of India, Quarterly Bulletin. Various issues.

# APPENDIX C

## THE DISCRIMINANT FUNCTION

A discriminant function was fitted to the data for classifying the farms. The computer package for discriminant analysis contained in SPSS (short for Statistical Package for Social Research) was utilized The result is presentd below:

$$Zi = -1.40083 + .0028X_1 + .0257X_2 -.0108X_3 + 0.0196X_4 + .0102X_5 + .0058X_6 + .0016X_7 + .0007X_8 -.0007X_9 + .028X_{10} + .0002X_{13} + .0016X_{15} + .1464X_{16}$$

where:

Zi = The individual farm's discriminant score.

$X_1$ = Per hectare expenditure on fertilizer.

$X_2$ = Per hectare expenditure on irrigation.

$X_3$ = Percentage area in gochani.

$X_4$ = Percentage area in pea.

$X_5$ = Percentage area in gram.

$X_6$ = Modernization in irrigation.

$X_7$ = Modernization in mechanization.

$X_8$ = Percentage area in wheat.

$X_9$ = Percentage area in paddy.

$X_{10}$ = Percentage area in maize.

$X_{13}$ = Percentage irrigated area in maize.

$X_{15}$ = Extent of consolidation of landholding.

$X_{16}$ = Per hectare expenditure on storage arrangement.

# APPENDIX D

## CHANGES IN CEREAL AND PULSE PRICES IN INDIA

In the Indian economy the modernization process in cereal crop production has alleviated the problem of food grain availability to a great extent. Despite the increasing population of the country, the import of food grains has declined each year since 1967. While this achievement is largely attributed to the modernization process, changes in cropping pattern also have much to do with it. Increased yield potentials of wheat and paddy crops have raised the competitive position of these crops in relation to other crops such as lentils, peas and other pulses.

The area devoted to wheat and paddy has increased considerably since 1965-66. Both the genetic breakthrough and the increase in area of wheat and paddy crops have been important factors in alleviating India's food production. However, the idea that India's food problems can be completely solved by boosting production of cereal crops and introducing modernization elements is fraught with many problems. A typical Indian diet consists of cereal grains as well as pulses. The availability of the latter is important in that it is the principal source of protein for most Indian people. Their importance would be more pronounced if a realistic consideration were given to the Hindu way of life. Vegetarian food is preferred to non-vegetarian food. In the absence of animal protein, pulses are used to fortify a vegetarian diet. The area of pulse crop development has been neglected. Research efforts in pulse crops have been less emphasized than those in wheat and paddy. The question of increasing the availability of pulses has not been tackled despite their significance in the overall food matrix of the Indian economy. The availability of protein on a per day per capita basis has been declining. The position obtaining in the country in regard to availability of pulses and food grains and their respective protein and food values over the period 1955-71 is presented in Table D.1.

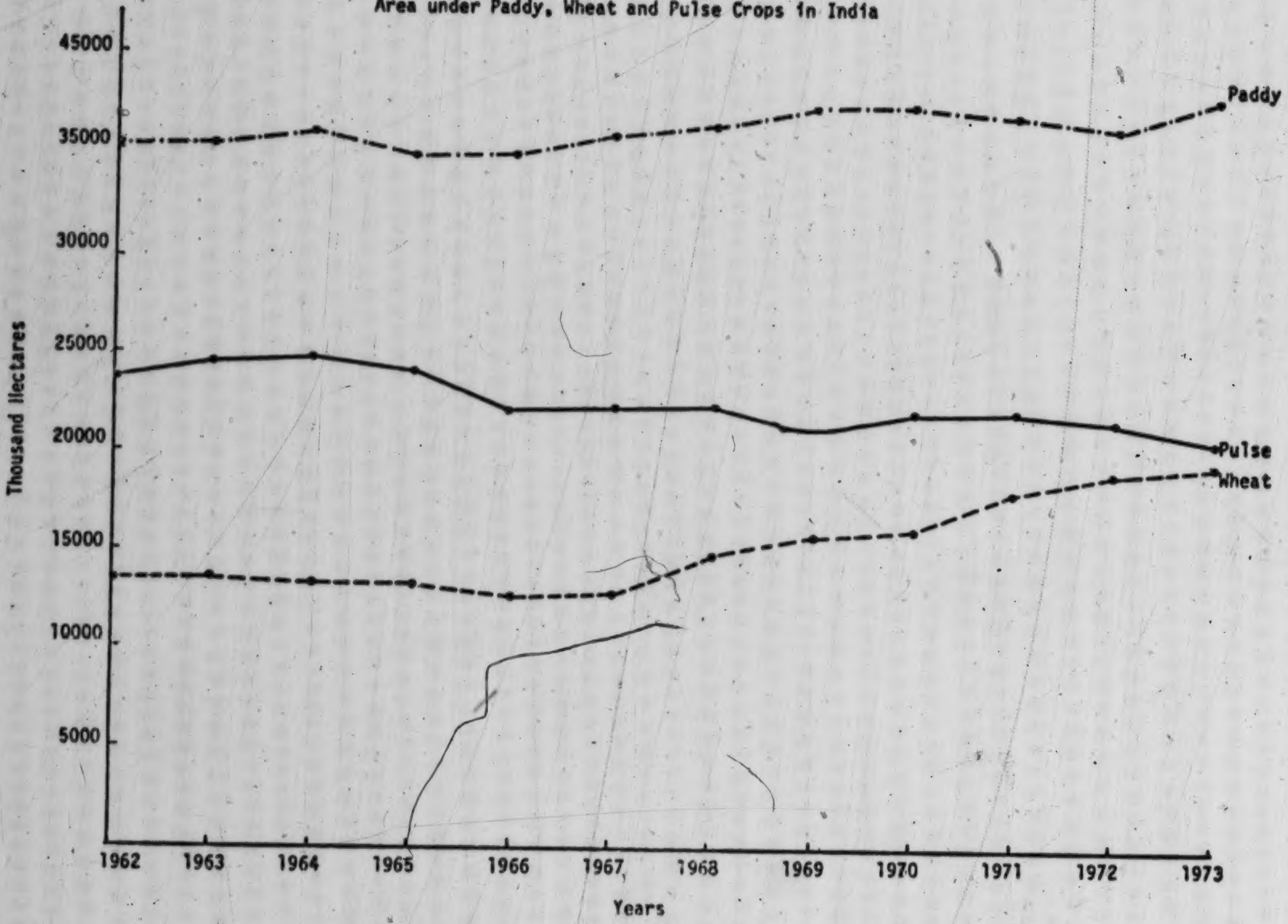
Concomitant with the decrease in the availability of protein over the years, the annual area devoted to pulse crops has also been declining. The total area under pulse crops declined from 24.2 million hectares in 1963 to 20.6 million hectares in 1973; that is, it decreased by 14.8 percent during the period. The area under wheat increased from 13.5 million hectares in 1963 to 19.4 million hectares in 1973; an increase of 43.7 percent during the period (see Figure 6).

The changes in the Indian agricultural economy are symptomatic of massive adjustments caused by the modernization process that has occured in the production of wheat and paddy crops. These changes are significant to the Indian economy and to the modernization of cereal crops. There are problems associated with such changes. A decrease in the area for pulse crops, lack of plant breeding research pertaining to pulse crops and relatively inelastic demand for pulses will impose serious consequences on the modernization process of cereal crops.

The interface between the availability of pulses and modernization of cereal crops can be brought into focus by examining the comparative statics of prices and production of cereal food grains and pulses in the Indian economy and their influence on the decision making process of the farmers. In India, the area in cereal crops has been increasing because of the increased yield potentials of wheat and paddy crops. Since

FIGURE 6

Area under Paddy, Wheat and Pulse Crops in India



## Table D.1

## PER CAPITA PER DAY AVAILABILITY OF CEREALS AND PULSES: THEIR ENERGY VALUE AND PROTEIN CONTENT (1955-71).

| | Per Capita Availability of Cereals (gram/day) | Per Capita Availability of Pulse (gram/day) | Per Capita Energy Supplied by Cereals and Pulses (KJ/day) | Per Capita Protein Supplied by Pulses (grams/day) |
|---|---|---|---|---|
| 1955 | 372.6 | 71.5 | 6,446 | 13.7 |
| 1956 | 360.1 | 70.5 | 6,061 | 13.5 |
| 1957 | 374.5 | 58.5 | 6,300 | 11.2 |
| 1958 | 349.5 | 74.5 | 6,149 | 14.4 |
| 1959 | 392.7 | 65.3 | 6,660 | 12.5 |
| 1960 | 382.1 | 68.7 | 6,547 | 13.2 |
| 1961 | 398.7 | 69.1 | 6,802 | 13.3 |
| 1962 | 400.7 | 62.4 | 6,744 | 12.0 |
| 1963 | 382.4 | 59.6 | 6,434 | 11.4 |
| 1964 | 398.2 | 50.7 | 6,551 | 9.7 |
| 1965 | 414.8 | 61.1 | 6,928 | 11.7 |
| 1966 | 355.9 | 47.8 | 5,890 | 9.2 |
| 1967 | 356.7 | 39.1 | 5,789 | 7.5 |
| 1968 | 396.9 | 55.2 | 6,589 | 10.6 |
| 1969 | 390.9 | 46.5 | 6,388 | 8.9 |
| 1970 | 394.3 | 50.9 | 6,497 | 9.8 |
| 1971 | 407.6 | 49.2 | 6,668 | 9.4 |

**Note:** In computing the amount of energy contained in cereals and pulses it was assumed that while each gram of cereal consists of 14.78 kilojoules of energy, the same quantity of pulse consists of 13.3 kilojoules of energy. The protein content of pulses was assumed as 19.23 percent.

**Source:** The information regarding per capita availability of cereals and pulses were collected from two issues of Economic Survey. (Government of India: 1968-69; 1971-72).

on a per capita basis the arable land is too small,[1] the increase in area in cereal crops results in a decrease in area in pulse crops and an increase in the relative prices of pulses. The relative prices of pulses may go up considerably and despite the modernization process, the relative profitability of cereal crops may be affected.[2] Hence, for the maintenance of the modernization process in Indian agriculture, knowledge about the price changes of both cereal food grains and pulses would appear to be very important.

If pulse prices keep on increasing relative to cereal grain prices, the adoption of high yielding varieties of crops will be adversely affected. The trend in pulse prices warrants an inquiry into why pulse prices are increasing more rapidly than those of cereals.

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[1] In India, the total arable land is small on a per capita basis. It has been argued that the supply of arable land for cultivation can be increased by introducing multiple cropping systems. But the scope for augumenting the arable land in India is very limited. Farmers already cultivate two or more crops during a year. With the available technical knowledge of crop production, the possibility of making rapid strides in increasing the area of crops in India is limited. This possibility can take place only if the photo period required by crops such as wheat and paddy is substantially curtailed (of course, without affecting the existing production performance) through plant breeding research.

[2] In the literature on subsistence agriculture, the role of prices as allocators of resources has long been recognized. The question of whether farmers would allocate larger areas to pulse crops in the event of a drastic increase in pulse prices has general validity. The reader is referred to Raj Krishna, "Farm Supply Response in India, Pakistan: A Case Study of the Punjab Region," Economic Journal, Vol. 73, No . 291 (September 1963), pp. 477-487, and Jere R. Behrman, "Supply Response and the Modernization of Peasant Agriculture: A Case Study of Four Annual Crops in Thailand," Subsistence Agriculture and Economic Development, ed. Clifton R. Wharton, Jr. (Chicago: Aldine Publishing Co., 1969), pp. 232-242.

## Factors Affecting Food Prices in India

### Consumption Habits

In an economy which is largely agricultural and relatively less monetized than advanced countries, cultural factors play a dominant role in the consumption of goods and services. Because vegetarianism is an ideal in the Hindu way of life, the significance of pulse in India is based upon both cultural and nutritional aspects.[1]

A complementary relationship exists between consumption of cereals and pulses. In the absense of substitute commodities for pulses, a decrease in availability of pulses has a pronounced effect on pulse prices. In view of the fact that habit pattern in consumption favour pulse crops, pulse prices are likely to increase further.

### Climate

The food supply in India in a given year largely depends upon the adequacy of rainfall and its distribution over the cropping period. Due to erratic fluctuations in rainfall in past years, food production has been subject to variation. Prices have also varied. Although vigorous efforts have been made to develop irrigation and power, irrigation facilities on farms are not adequate. Erratic fluctuations in rainfall affect all kinds of crops (cereals, pulses, oil, sugarcane, vegetables) except millet.

### Marketing and Storage of Food Commodities

With the increased adoption of high yielding varieties of wheat and paddy crops in India, government marketing efforts have been largely confined to these two commodities. Marketing of pulses is still channelled through traditional institutions which are known for their hoarding and speculative activities. Storage facilities at the farm level are meagre. Farmers usually store the produce in their dwelling places. With the establishment of the Food Corporation of India and the provincial warehousing corporations, storage arrangements for wheat and paddy have improved. The cereal commodities have been the main beneficiaries of the government programmes for marketing and storage facilities. The marketing and storage of pulse commodities remains a problem to which the difference between pulse and cereal prices is associated.

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[1] For an extensive discussion on the role of pulses in the Indian context, see: P.V. Sukhatme, Feeding India's Growing Millions (New York: Asia Publishing House, 1965), pp. 64-75.

### Money Supply

The Reserve Bank of India exercises control over the money supply in response to economic and political needs. The Reserve Bank has been increasing the money supply since 1948. While the relevance of such decisions is beyond the scope of this study, the consequences of continued increases in money supply have a direct bearing on food prices.

In the analysis of aggregate economic activities, an increase in the money supply under certain conditions will result in an increase in price levels. The response of individual commodity prices reflects the relative supply and demand of those commodities in the economy. Changes in food price also occur whenever the money supply is increased. The nature and extent of changes in various food commodity prices depend upon the total availability of commodities.

## A Regression Model of Price Changes Over Time

A naive predictive model was used to explore the increases in prices of cereal and pulse commodities. The model included three variables, namely, the price of a particular commodity, the per capita availability of the commodity and the money supply. It was assumed that the price of a particular commodity is affected by the per capita availability of that commodity (a proxy per supply conditions) in the economy and by the money supply (a proxy for general price level).

The relationship between the price of a commodity and the per capita availability of that commodity is expected to be negative. The impact of an increase in money supply on the prices of pulses and cereals is expected to be positive (meaning that as the money supply increases, the prices of cereals and pulses will increase). The explanatory power of the variable (i.e., the money supply) will depend upon the statistical significance and magnitude of the coefficient associated with it.

## Model Formulation

The price changes in cereal food grains and pulses can be represented by a model consisting of commodity price as a dependent variable and per capita availability and money supply as independent variables. For the price variation in each of the commodities, the model can be conceptualized as follows:

$$Pc = f(M,Ac,U) \quad (1)$$

$$Pp = f(M,Ap,U) \quad (2)$$

where:

Pc = Price index of cereal food grains,

Pp = Price index of pulses,

M = Money supply consisting of:

1) Currency in circulation,

2) Cash on hand in banks,

3) Net demand deposits in banks,

4) Other deposits with the Reserve Bank of India,[1]

$Ac$ = Per capita availability of cereals (grams per day),

$Ap$ = Per capita availability of pulses (grams per day),

$U$ = Error term.

This conceptualization can be represented algebraically as follows:

$$Pc = \alpha \pm \beta_1 M \pm \beta_2 A_c \tag{3}$$

$$Pp = \alpha \pm \beta_1 M \pm \beta_2 Ap \tag{4}$$

The nature of the relationship between the dependent variable and each of the independent variables in the above models was stipulated as follows:

1. $\frac{\delta Pc}{\delta M} > 0$
2. $\frac{\delta Pc}{\delta Ac} < 0$
3. $\frac{\delta Pp}{\delta M} > 0$
4. $\frac{\delta Pp}{\delta Ap} < 0$

## Data Analysis, Results and Discussion

Data for the period 1956-71 were collected for each of the variables indicated in expression (3) and (4). Linear regression equations were fit to the data. The results obtained are as follows:

$$\underset{(2.052)}{Pc = 196.64239} + \underset{(9.456)}{0.026438M} - \underset{(-1.675)}{0.433166\ Ac} \ldots \quad R^2 = 0.8679 \tag{5}$$

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[1] These exclude the deposits of the commercial banks.

$$Pp = 369.877929 + 0.018322M - 4.795399\ Ap \ldots \qquad (6)$$
$$(4.558) \qquad (3.072) \qquad (-4.602) \qquad R^2 = 0.8917$$

NOTE: Figures in parantheses are t-values of the respective coefficients.

There are two sets of results in the form of two regression equations-- one for price change in cereals and the other for price change in pulses. Discussion of the empirical significane of each variable in both regression equations follows.

Equation (5)-- This equation represents the nature of the dependence of cereal prices on the money supply and per capita availability of cereals. As to the nature of the relationships, two stipulations were made: (1) that an increase in money supply in the economy results in an increase in cereal prices, and (2) that an increase in per capita availability of cereals in the economy should lower the prices of cereals. The results obtained in equation (5) are in conformance with the stipulations-- the sign of the coefficient associated with money supply is positive and that of per capita availability of cereals is negative.

The coefficient of multiple determination indicates that nearly 87 percent of the variation in cereal prices is explained by the two independent variables. The coefficient associated with money supply is significantly different from zero at the 5 percent level of probability. The coefficient associated with per capita availability of cereals is not significantly different from zero at the 5 percent level of probability.

Equation (6)-- This equation represents the nature of the dependence of pulse prices on the money supply and per capita availability of pulses. The assumptions involved in this model are similar to the model for cereal price variation; that is, an increase in money supply has a positive effect and an increase in per capita availability of pulses has a negative effect on the pulse prices. The signs of the coefficients conform with the assumptions.

The coefficient of multiple determination shows that 89 percent of the variation in the pulse prices is explained by the two variables. As for the reliability of the individual coefficients associated with the variables both are significantly different from zero at the 5 percent level.

## Implications of Results on Modernizing Indian Agriculture

From the results presented in the preceding section, it would appear that the magnitude of increase in pulse prices due to a decrease in per capita availability of pulses will be larger than the increase in cereal prices for a similar decrease in per capita availability of cereals. The coefficient associated with the per capita availability of pulses is -4.79 and is significantly different from zero. The coefficient associated with the per capita availability of cereals is -0.433 and is not significantly different from zero. The trends obtaining for the areas in cereal and pulse crops suggest that the area under the latter has been decreasing. If this trend continues, the per capita availability of pulses will further decline and therefore the price of pulses will further increase. Consequently, a point may come when the profitability of cultivating pulses may outweigh the profitability of cereals and farmers may start allocating larger areas for pulse crops.

The Government of India has repeatedly emphasized the significance of increased adoption of high yielding varieties of cereal crops in its programmes for agricultural modernization. The dramatic increases in pulse prices may affect such strategy adversely because output prices enter into the decision making process of farmers. A relative increase in pulse prices may result in decreased adoption of the high yielding varieties of crops because the pulse crops compete with cereal crops for land. Since pulse crops can thrive well under poor moisture and low nutrient conditions, the switch over from cereal to pulse crops may temporarily dampen the demand for fertilizers and irrigation pumps.

## APPENDIX E

### TABLE E-1

### EXPENDITURE (Rs) PER HECTARE OF WHEAT ON MODERNIZED AND NONMODERNIZED FARMS

| Items | Group[1] | Mean Value of Per Hectare Expenditure (Rs) | Standard Deviation | 'T' Ratio |
|---|---|---|---|---|
| Human Labour | I | 330.9639 | 120.363 | -0.01 |
| | II | 331.2720 | 126.930 | |
| Bullock Power | I | 86.4763 | 35.077 | -0.67 |
| | II | 90.4220 | 34.563 | |
| Seed | I | 57.7638 | 14.613 | -0.12 |
| | II | 58.2195 | 29.810 | |
| Fertilizer | I | 64.2893 | 45.124 | 1.84* |
| | II | 49.5148 | 50.928 | |
| Irrigation | I | 26.1937 | 7.122 | 7.14** |
| | II | 14.5220 | 12.741 | |

[1] Group I refers to modernized farms; group II refers to nonmodernized farms.

* Represents significance at the 10 percent level of probability.

** Represents significance at the 5 percent level of probability.

## TABLE E-2

## ENERGY INPUT (MEGAJOULES) PER HECTARE OF WHEAT ON MODERNIZED AND NONMODERNIZED FARMS

| Source | Group[1] | Mean Value of Energy Expenditure (Megajoules) | Standard Deviation | 'T' Ratio |
|---|---|---|---|---|
| Human Labour | I | 88.6976 | 32.260 | -0.01 |
| | II | 88.7805 | 34.018 | |
| Bullock Power | I | 486.7830 | 197.432 | -0.67 |
| | II | 508.9890 | 194.554 | |
| Seed | I | 1,048.8633 | 265.344 | -0.12 |
| | II | 1,057.1353 | 541.299 | |
| Fertilizer | I | 1,215.0671 | 852.840 | 1.84* |
| | II | 935.8206 | 962.543 | |
| Irrigation | I | 471.4846 | 128.184 | 7.14** |
| | II | 261.3979 | 229.349 | |

[1] Group I refers to modernized farms; group II refers to nonmodernized farms.

* Represents significance at the 10 percent level of probability.

** Represents significance at the 5 percent level of probability.